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SOCIETY AND RELATED ACTIVITIES

International Acetylene Association

The Annual Convention of the International Acetylene Association will be held September 26th to 29th at the Congress Hotel, Chicago. The American Gas Association is holding its convention at the same time.

National Weld Testing Bureau

This Division has been organized by the Pittsburgh Testing Laboratory to meet the needs of industry. Inspection of welded structures and practice is also a function of the Division, as well as special welding problems. The service has been formed primarily to meet the needs for qualifying welders in connection with the processes and procedures of manufacturers to be used in important construction and production work. Mr. James W. Owens is Director of the Bureau.

The First Hundred Years

(*Reprinted from March 2, 1933 issue of Engineering News-Record.*)

It is one of the ironies of fate that an exposition depicting the remarkable progress of the first hundred years of the partnership between science and industry should have to be held at a time when progress seems almost to have ceased. Yet Chicago's second world's fair—its Century of Progress Exposition—is by no means the unwelcome and untimely visitor that this statement implies. The exposition comes at a time when we are sorely in need of a dramatic reminder that we have progressed far in this generation of ours; that our advantages in comforts and pleasures are of a kind and a degree unsurpassed in history and undreamed of by our ancestors. True, it may also raise the question whether our material advance has not outdistanced our cultural and social improvement, and perhaps outmoded some of our long-established principles of economics. But here again the exposition will prove a benefit, for by fostering a re-birth of an appreciation of material gains it will serve as a check on those who would scrap industry in order to solve the problems that industry has created. We cannot live without the fruits of science and industry. If at present it also seems that neither can we live with them, it does not follow that we should give them up. Rather the problem is to plan so that cultural, social and economic advance will supplement technical and scientific improvement. The several factors are theoretically compatible. A Century of Progress Exposition should help make it plain that they must be made practically so.

Alloys of Iron Research Monograph Series

This book published by the McGraw-Hill Book Company was prepared by a Committee of The Engineering Foundation. These monographs are a concise but comprehensive critical summary of research on ferrous alloys as reported in the technical literature of the world. They contain a discussion of all available data on binary and higher ferrous alloy systems and on the effect of the alloying elements on carbon steel and on simple and complex alloy steels and special alloy cast irons. They provide a reliable foundation for further research and in one volume supply to the practical metallurgist, steel worker, foundryman and engineer the essential information now scattered through more than two thousand journals and text-books in many languages.

The authors are responsible for selection and evaluation of the data, for arrangement of subject matter and for style of presentation. Each book, however, has been reviewed in manuscript by men especially qualified to criticize all statements. Indebtedness for this cooperation is recognized in the acknowledgments. Finally, each manuscript has been reviewed and approved for publication by the Iron Alloys Committee.

Steel Framing for Small Residences

During recent years the subject of steel houses has aroused keen interest among architects, builders and real estate men, and this interest has been widely reflected in the magazines and the daily press. The United States Steel Corporation has issued a booklet entitled, "Steel Framing for Small Residences."

The compilers of the booklet quite evidently believe that the future development of steel in this field will be found in houses of individual, non-standardized design, as distinguished from the mass production house, and they look to architects, builders and local fabricating shops as the natural and most promising avenue of exploitation.

The publication is the outcome of a survey made by a trade research committee drawn from subsidiary companies of the United States Steel Corporation for the purpose of investigating the demand for steel in residence construction. Nearly one hundred different systems of construction were studied, and a number of the residences built in accordance with these systems were inspected by representatives of the committee. The following conclusions were indicated:

1. There exists a wide-spread interest in steel framed residences. The principal demand is for small ones and two-family houses of individual design.
2. Steel can be advantageously used in the construction of residences of any architectural style or arrangement to provide a frame that will not shrink, is inherently non-combustible, sanitary and rigid, resists the destructive attack of insects and can readily be made permanent.
3. Certain new practices can be employed with safety and economy in the design of the steel framework for small residences along lines not contemplated in current engineering handbooks.
4. With the aid of suitable information the steel framework can be designed by architects as readily as in the case of older forms of construction.
5. The details of the steelwork can be developed to advantage in cooperation with the personnel of a fabricating shop located in the vicinity of each job.

The fabrication and erection requirements are simple and are well suited to the equipment of the smaller structural or sheet metal shops.

The booklet specifically aims to provide architects, builders and fabricators with convenient information on the safe, practical and economic use of steel in the framework of small residences. The new practices are explained and subjected to rule, and the manner in which they can be applied is exemplified. By means of detailed steps, drawings and photographs, one section of the booklet shows how the arrangement and sizes of all the steel members needed in framing a typical house may be easily determined. Its pages also illustrate a number of framing systems composed either of standard structural shapes or of sheet metal, and it presents for the first time a table that should be helpful in the design and computation of thin sheet metal sections. The construction used in the residences illustrated will doubtless suggest to the architect and builder many other variations in construction methods.

In order to simplify the design of steel framing for residences, rules for proportioning individual members are given, and specially arranged tables of safe loads make their selection an easy matter. The difference between the conditions which govern the use of steel in tier buildings and in residences is emphasized.

A selected group of steel products suitable for residence framing is listed for ready reference, containing the following:

Structural shapes, including two new light weight beam sections
Plates, both sheared and universal
Pipe for column purposes
Hot-rolled strip
Annealed sheets

The booklet, attractively bound in 8½ x 11-in. size, contains 56 pages. Copies may be secured from the sales offices of the subsidiary companies of the United States Steel Corporation.

German Acetylene Association Meeting

The German Acetylene Association held a meeting in Munchen on September 15th to 17th. A number of technical papers were presented dealing with the strengths of welded joints, procedures, impact studies and experimental investigations of high pressure acetylene installations.

SECTION ACTIVITIES

CHICAGO

At a special meeting of the Chicago Section held in the Joseph Urban Room in the Congress Hotel on June 29th, several papers were read giving details of some of the welded construction in evidence at the Chicago World's Fair. This meeting was held during Engineering Week to give visiting engineers an opportunity to become informed on the welding and cutting processes. A general paper on the application of welding in allied processes and dealing mostly with the application of welding in the buildings at the Fair was read by J. M. Jardine of the Western Welding & Boiler Repairing Co., Chicago. This was followed by an illustrated talk on the "Design and Construction of the Sky-Ride Towers," given by A. L. Wilson of the Mississppi Valley Structural Steel Co. "The Application of Welding and Cutting in the Fabrication of the Nash-Whiting Parking Tower at the World's Fair" was given by Mr. W. B. Keelor of the Whiting Corp. The papers were followed by a general discussion. After the meeting a dinner was held in the same room as the meeting. A distinguished guest at the dinner was Dr. Jean Piccard, who is to participate in the balloon ascension into the stratosphere from the World's Fair grounds.

NORTHERN NEW YORK

The following Officers of the Northern New York Section have been elected to office:

Chairman—R. T. Gillette, General Electric Co.

1st Vice-Chairman—L. R. Leveen, General Electric Co.

2nd Vice-Chairman—M. Unger, General Electric Company.

Secretary-Treasurer—R. W. Clark, General Electric Co.

Two Directors for three years:

T. R. Lawson, Civil Eng. Dept., Rensselaer Polytechnic Inst.

V. J. Chapman, General Electric Company.

Director for unexpired term of Mr. H. W. Tobey—O. A. Tilton, General Electric Co.

Director at Large—A. Vogel, General Electric Company.

PHILADELPHIA

The September meeting of this Section will be held on the 18th. Frank P. McKibben, President of the Society, will present an address on, "A Review of Welding."

SAN FRANCISCO

A most interesting meeting of the San Francisco Section was held on July 28th in Wheeler Hall of University of California Campus. Two splendid films, "How You See" and "First Complete Industrial Survey Made at California Wire Cloth Company," were shown. The speakers of the evening were Dr. T. A. Brombach and Mr. A. R. Reinke of the Department of Physics Optometry, University of California, who spoke on "Eye Hazards in Industry" and "The Use and Value of Absorption Lenses in Electric and Acetylene Welding."

Members and guests of the San Francisco Section on August 26th were given an opportunity to inspect the work being done on the great Oakland-San Francisco Bay Bridge, at the invitation of the Moore Drydock and Shipbuilding Co. yard. A short meeting was held in the main office building after which the inspection of the yard was made.

DETROIT

The Detroit Section has been active in arranging the numerous details in connection with the Fall Meeting of the AMERICAN WELDING SOCIETY which will be held on October 2nd to 6th in connection with the Metal Congress and Exposition.

The Section has furnished several of the important technical papers to be presented at the Fall Meeting and has arranged an inspection trip. This trip includes visits to the welding departments of the Kelsey Hayes Wheel Co., The Ford Motor Co. and an automobile body plant.

The Section has also been instrumental in arranging for attendance at a play, "The Prosperity Process," a four-act drama staged by the AMERICAN WELDING SOCIETY with the cooperation of the International Acetylene Association at the Masonic Temple on October 3rd.

Arrangements for the annual banquet and dinner dance of the SOCIETY, as well as registration facilities and numerous other details, were provided by the Section.

Membership Drive

The Membership Committee urgently requests the cooperation of every member of the Society in bringing in one new member before January 1st.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

United States Civil Service Commissions announced open competitive examinations for Senior Engineer, Engineer, Associate Engineer and Assistant Engineer at salaries ranging from $2600 to $5400 a year for aeronautical, agricultural, civil, construction, electrical, heating and ventilating, highway, mechanical, mining, radio, structural and telephone engineering. Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post office or custom house in any city, or from the United States Civil Service Commission, Washington, D. C.

The United States Civil Service Commission, Washington, D. C., announces competitive examination for Marine Engineer, Associate Marine Engineer and Assistant Marine Engineer. Entrance salary range from $2600 to $4600 per year less certain deductions. Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post office or custom house in any city.

In addition to the above, Engineering Draftsmen for work on ships are desired. Salaries range from $1440 to $2600 per year. Optional branches are ship hull, ship piping, ship ventilation, marine engines and boilers and electrical (ship).

SERVICES AVAILABLE

A-166. Electric Welder. Considered a first class operator. Thirteen years' experience both at home and abroad, of which ten years have been spent as a Foreman and Instructor. Passed tests for Class II, A. S. M. E. Code for Unfired Pressure Vessels. Excellent references.

A-201. Welding research engineer desires position. Have received several degrees including one in Chemistry and Metallurgy and Physical Metallurgy. Have devoted attention to research work in the welding field. Am anxious to locate with some company that intends to carry out a development program in which the above fundamental knowledge can be utilized.

A-202. Arc and Gas Welder. Twelve years' experience. Desires position in New York City.

Welded Construction at "A Century of Progress"

By J. M. JARDINE

✦ Paper presented at the June 29th Meeting of the Chicago Section, A. W. S., by J. M. Jardine of the Western Welding & Boiler Repairing Co.

This Welded Aluminum Truck-Tank Is One of the Features of the International Harvester Exhibit

CHICAGO'S International Exposition, A Century of Progress, presents many interesting examples of the successful application of arc welding to various types of structures. I have been asked to describe some of these structures and to touch upon other uses of the welding and allied processes evident at the Fair.

As a bit of preliminary information, I believe it advisable to point out that practically all the structures of A Century of Progress are only of temporary construction, and, as a consequence, the dismantling, salvage cost and return were decisive factors in eliminating welding to a very great extent. While this condition discarded a lot of welding, I believe it produced evidence of the great possibility of welding in the structural field.

Before any welding was specified, an engineering committee of A Century of Progress viewed a demonstration of various types of welded joints that might be adaptable in their building program. The first test made was to weld floor joists of the Truscon type to beams, using $^1/_2$-in. electric welds to tack the flange of the joist down to the beam.

From the standpoints of cost and engineering, the test was entirely satisfactory. However, the results of dismantling and salvage were not so good. We tried to break the $^1/_2$-in. tack welds loose from the joists or beams, but were not successful until part of the flange of the joists tore out and the joists became distorted. This completed, we found that we still had the weld and part of the joists attached to the beams, which could not be salvaged for resale until these parts had been removed. The oxyacetylene cutting torch was tried, as well as the air hammer. But the committee decided it would be better, from a salvage standpoint, to use the bolted clamp method of erection.

You can readily see that, for permanent construction, welding would be entirely satisfactory on this class of work.

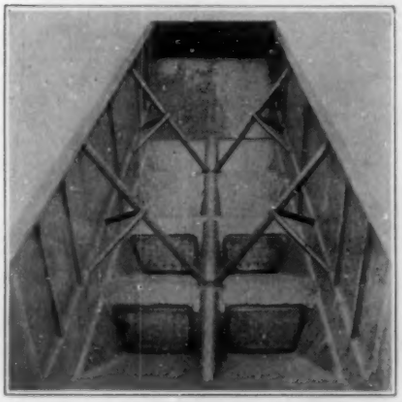
The next test was to install cross-bridging between joists. Several bays were welded up in this manner. The bottom end of the bridging is V'd out to straddle the lower flange of the joist, then a tack weld about $^1/_4$ in. long is made between the top of the joist and the top end of the bridging. A concentrated floor-load test was made which was entirely satisfactory. Our observation would lead us to believe that the welded bridging is superior to any other method of joining, due to the fact that there is just sufficient contraction in the weld as it cools to make the flooring very rigid.

Comparative figures on costs of welded and bolted erection would undoubtedly be of interest, but unfortunately there does not seem to be any costs available on bolted construction, and welding was all done at Chicago labor costs. Therefore, it will be more helpful just to give the time required to do a given amount of welding. A fair average rate of welding for bridging is one weld per minute.

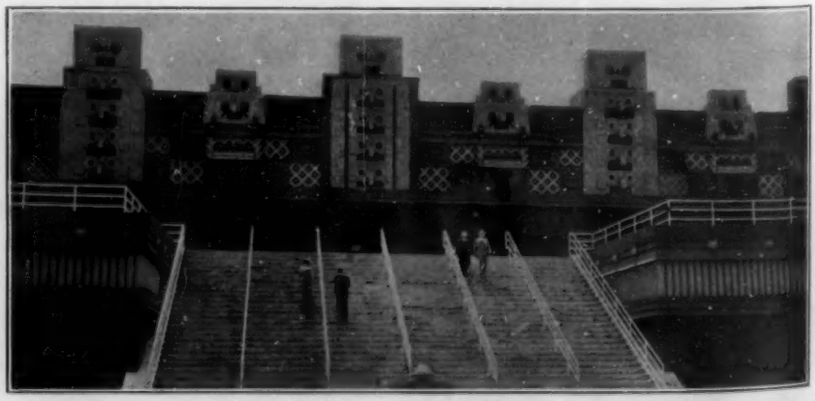
About 100,000 welded bridgings were used on the following buildings: Sears Roebuck, Hall of Science, General Exhibits, Polish Building, Dairy Building, Electrical Building, States Group and several smaller buildings.

A visitor at A Century of Progress not interested in welding might enter the main gate and go through the entire exhibition without noticing at any time a single welded job, yet welded construction abounds everywhere.

As you approach the Fair Grounds from 12th Street, you will see several foot bridges. If you will observe carefully, you will see that all the lally columns are



View of Inside of Welded Car



An Ancient Temple Reconstructed. The Nunnery at Uxmal, One of the Most Elaborate of the Mayan Religious Buildings, Is Built in Replica at A Century of Progress Exposition. Two Years Were Required by an Expedition into Yucatan Headed by Dr. Franz Blom to Collect the Data Necessary for the Structure. These Handrails, as Well as All Others Throughout the Fair Grounds, Are Welded

Flash Welder in Operation in the General Motors Building

welded, eliminating unsightly H-beams, riveted fabricated columns or other structural shapes. A little farther along the journey you will come to the main entrance. After dispossessing yourself of the admission price, you will notice a fence of welded steel pipe all around you, and the turnstiles you go through are welded. Over your head is a roof partly made up of welded trusses and welded bridging.

Should you be wise, you will take a bus or wheel-chair, each of which utilized welding in its construction. However, if you decide to walk, you first approach the Administration Building, all along the front of which you will notice welded trellises. Should you go into the building, you will notice welded furniture and a refrigerator, which I am told would not be as successful if welding were not available.

After leaving the Administration Building, you are struck with the beauty of the Avenue of Flags. An examination of the 47 standards along this street will reveal an all-welded job of very striking design with welded canopy frames lining both sides of the street.

The Sears Roebuck Building is the first on our right, and I think of the welded bridging and the beautiful welded dome. Moreover, an examination of the contents of this building reveals a multitude of welded jobs. The dome, of stainless steel, rests on ribs made of T's bent to the proper radius. This framework is supported on eight wheels which run along the inside web of H-beams formed to the correct radius and welded to supporting framework. The dome is 16 ft. in diameter.

We pass under the cableway of the imposing Sky-Ride, which Mr. Wilson has already described, and continue south to the Hall of Science. Apart from the welded bridging in this building, there are many other welded jobs. In one part of this building an overhanging projection was needed; junior beams were used and welded into place.

In the main hall of this building is a huge globe under which are cases displaying samples of many of the chemical elements and showing their places in the periodic system. This entire structure, including the globe, is supported by a welded framework. At the opposite end of this hall is the actual welded aluminum gondola used by Professor Auguste Piccard in his epoch-making flight into the stratosphere last August.

Near the Hall of Science are the Jehol Temple and the Japanese Pavilion. I found that these all-wooden buildings have fence posts and gates that are welded to some extent.

As we pass under a balcony connecting the Hall of Science with the General Exhibits Building, we pause a moment to examine the uncovered bridging overhead,

Welded Frameless House on Exhibit in the Housing Group at the Fair

which appears to be a part of the joists inasmuch as the welding has eliminated all mechanical connections.

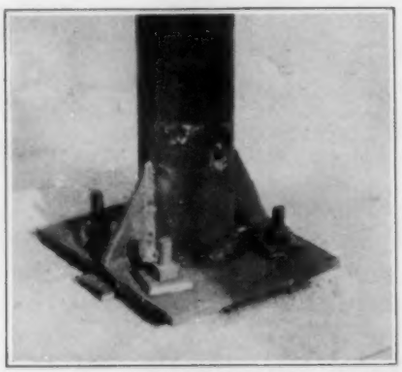
Continuing south, we come to the Sinclair Exhibit of Prehistoric Animals. The construction of these animated life-size creatures involved considerable welding for the framework. From here to the General Motors Building we see welded flagpoles and other forms of standards, as well as other evidences of welding in some of the buildings. For example, the frameless house in the Housing Group was so inviting that we went through it and found evidences of welding in the solarium on the roof and on the stairs leading from the roof to the ground. The wall and floor sections of this house were spot welded in the shop and field erected by mechanical forms of fastening.

The Whirlplane, located at 26th St., presents a very interesting welding job, utilizing about 50% welded and 50% riveted construction. However, we are informed by the owner that his next job will be all-welded, using tubular construction. The reason for this change being to get down to an absolute minimum weight and a more artistic job.

Welded Skeleton, 70 Ft. Long, of the Brontosaurus, for the Sinclair Prehistoric Exhibit

Electric arc, gas cutting and oxyacetylene welding were used to fabricate the present equipment. We believe an examination of this job will show that the owner, an ex-airplane pilot, has absolute confidence in welded construction.

We now find ourselves in the General Motors Building. We reach a balcony and look below us at a complete automobile-assembly plant with two flash welders in operation, showering sparks as they bring the edges of the body panels together and flash out the molten metal along the welded seams. Rising from where we stand are high roof arches made of 18-in. I-beams on which the cutting torch and welding arc have been used. Sixteen of these arches span the assembly floor. The general curvature of each arch was obtained by cutting out a notch by means of a cutting torch at each joint, so the entire



Column Base Cut from I-Beam, Inserted in Slats in Column, Then Welded

beam is cut through except the upper flange, then bending the beams the cut edges meet and fill the kerf with weld metal. Three sections so formed are jointed together with splice plates to form a single arch.

As we leave the General Motors Building we see ahead of us a beautiful elevated approach to the Chrysler Building and once more we see some artistic columns supporting the elevated approach—welded construction again. Instead of employing the usual base plates top and bottom, these tubular columns have T-sections cut from Bethlehem beams by means of a torch with the flange of the T inserted into slots cut into the columns, where again the cutting torch was used. Then fillet welds were laid where the T-section and the column joined.

We continue on to the Travel and Transport Building. Here, if one wants to find welding, look at the airplanes, tractors, locomotives and Pullman cars—they all have welding in their construction. An 8-hopper car on the siding south of the building is noted for having a one-piece cast underframe and all-welded superstructure. It is a noteworthy demonstration of how welding and castings are combined to simplify design and construction and make a stronger, more rigid structure.

South of the Travel and Transport Building, we come to the Nash Whiting parking tower, which is in continuous operation displaying 16 models of automobiles. The mechanism of this parking machine and much of the supporting frame are completely welded. Some of the gears, all the links and the pinions were cut out of steel plate with the torch, using an automatic shape cutter. The edges of the pinions and links were left as cut without a machine finish. This tower and machine are outstanding contributions to the arts of shape-cutting and arc welding.

While in the south end of the Fair Grounds, a side trip to the Rosenwald Museum in Jackson Park will reveal a full-size coal-mine head that is all-welded, and various welding and cutting demonstrations of interest.

We will now go over to Northerly Island and, beginning at the south end, see what welding we can find there.

The columns supporting a canopy around Pabst's Blue Ribbon Casino show very similar welded construction to those on the elevated approach to the Chrysler Building, which we have already examined.

In the Electrical Building we find several interesting welding demonstrations. This building was partly welded, as were also the States Group and the Dairy Building and Polish Building, which lie farther north.

In the Agricultural Building we find an interesting all-welded aluminum truck-tank, highly polished, and the welded seems cannot be detected by the naked eye. This tank, because of its light weight, is built for a payload capacity 500 gallons in excess of that of a comparable steel tank, and this additional capacity, it is said, pays for the extra cost of the aluminum construction in a year's time.

In the field of metal spraying, which is allied to that of gas welding, there are several interesting applications of this process on the Fair Grounds.

For example, in the Agricultural Building, which we have just referred to, a strip of the concrete floor around the General Foods booth has been metal sprayed with brass, about 1200 sq. ft. of surface being covered.

Over in the General Exhibits Building, the Master Lock Co. has used metal spraying quite extensively in its exhibit for coating a lion's head, a hemisphere and a huge wooden lock. The plaster murals in the Brunswick-Balke Collender booth in the same building appear to be made of silver instead of plaster, because of the effect produced by the sprayed tin. These murals were put up in sections and the joints smoothed over with plaster. Air for the spraying process was furnished by a portable compressor stationed outside the building. These plaster murals were sprayed from four different angles, thus placing four coats of tin on the elevated surfaces and a fewer number on the low parts. After spraying, the tin was highlighted by hand with steel wool and lacquered to prevent tarnishing. Other examples of this process can also be seen in the booth of the National Cash Register Co. in this building and of the Hoover Co. in the Electrical Building.

No attempt is made in this paper to cover every application of welding and allied processes at the Fair, but enough information is given to show the dependence that is placed on these processes and how engineering and economic considerations have dictated their extensive use.

Member for Member Campaign

The Membership Committee is counting on every member to bring in one new member before January 1, 1934. Please do your share.

Maintenance, Alteration and Repair of Mechanical Equipment by Bronze-Welding

By R. B. AITCHISON

✦Paper presented by Mr. Aitchison of The Linde Air Products Company at a Joint Meeting held on June 6, 1933 of the New York Section, A. W. S., and the International Acetylene Association.

MAINTENANCE, alteration and repair of mechanical equipment is a large and varied subject. At every point in this vast field bronze-welding offers opportunities to effect savings, because:

1. Bronze-welding is dependable.
2. It is speedy.
3. It is simple in application.
4. It is a great saver of time and money.

The proof of these statements is that bronze-welding is finding more and more favor every day by both the industrial use of welding and the welding contractor. Those who desire detailed data regarding the fundamentals of bronze-welding are referred to a paper delivered before this Section of the AMERICAN WELDING SOCIETY on September 20th of last year entitled, "The Principles of Bronze-Welding."

In the time allotted it will not be possible to do more than to indicate briefly the wide variety of bronze-welding applications in many industries.

Power plants and users of steam engines of all types need boilers, boilers need feed water, and this is usually supplied by pumps. The cast-iron plungers on the boiler feed pumps of one concern gave them considerable trouble from corrosion and rapid wear. They bronze-welded one, first machining the whole pitted surface, and then, after a gentle but thorough preheat to protect

Fig. 1—Bronze-Welding Saved This Cast-Iron Manifold from the Scrap Pile for a Third the Cost of a New One

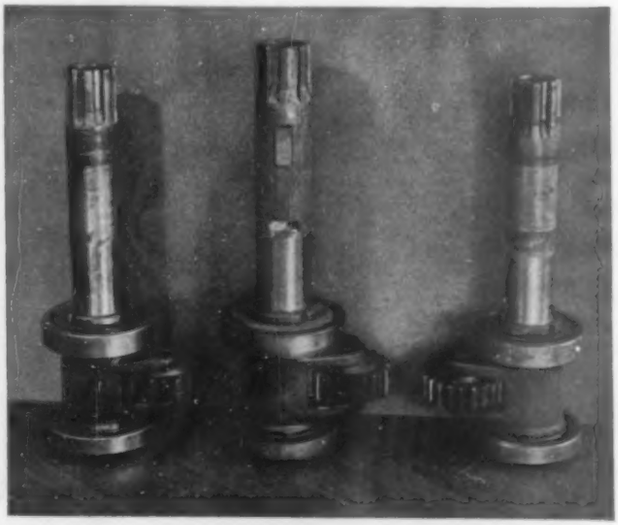


Fig. 2—Truck Rear Axle Housing Tubes Are Bronze-Surfaced and Machined to Fit at Point of Wear for a Very Small Fraction of New Cost

the plunger from excessive warpage, made the weld and machined the weld metal. All this cost $26.55. New plungers purchased in lots of six cost $40 each. The direct saving was thus $13.45, but, more important, the indirect saving through the now permanent bronze bushing will be several times the direct saving because corrosion will not affect the bronze as it did the iron. The concern is now bronze-welding all plungers.

The railroads have made most effective use of bronze-welding in the maintenance locomotives and other equipment. A large percentage of the steam locomotives in use in the country have had bronze-welding applied at some point.

Industrial companies having yard locomotives have not been quite as active as the railroads in taking advantage of the tremendous savings made possible through the correct application of bronze-welding, but they are forging ahead rapidly. One of them, for instance, has supplied data regarding some of the work they now do. To give an idea of the extent of the use of bronze-welding, the average amount of bronze-weld metal per job is given for several typical cases. For example, back-side rods are built up using an average of 10 lb. of bronze-welding rod; bull rings, up to 120 lb.; main-rod brasses, up to 40 lb.; cross-head gibs and side-lateral liners, 20 lb. In addition, high pressure valves, air-brake pistons and shafts of all descriptions are reclaimed by bronze-welding.

From railroad transportation to roadway transportation is not a big jump and it is interesting to note that fleet owners of buses and trucks are utilizing bronze-welding very effectively and in greater quantity every day. No fleet owner can very well afford to pass up the savings effected as well as the greater amount of active life of his trucks made possible by the utilization of bronze-welding. The innumerable parts of cylinders, valves, transmission, cooling system, etc., in fact, every division, major and minor, of the automotive power plant has a multitude of time and money-saving bronze-welding applications.

For example, here are some average costs by a maintenance garage of one large oil company whose trucks cover the country. Incidentally, some of these trucks are over 15 years old.

The cost of new replacement parts for the above totals $373.25. The reclamation cost for both bronze-welding and machining, where necessary, totals $21.52—a saving

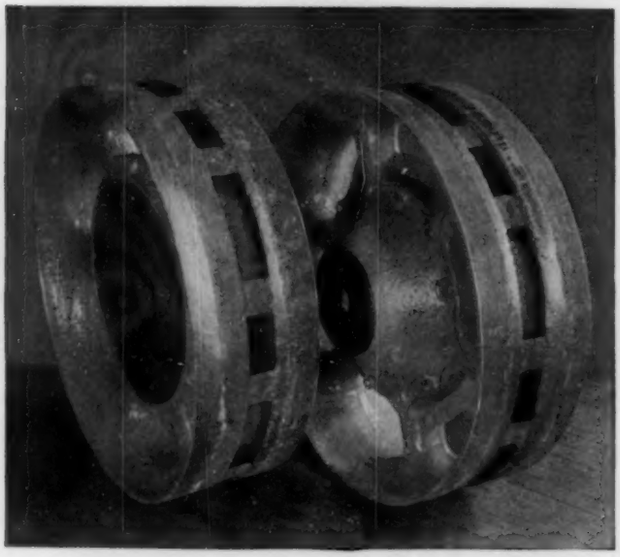


Fig. 3—Truck Rear Wheel Surfaces Rebuilt by Bronze-Welding the Worn Areas and Machining to Correct Size for One-Seventh the Cost When New

	Cost, New	Reclamation Cost, Average
Flywheels	$ 20.00	$3.50
Rear axle housing tubes	225.00	7.50
Universal joint yokes	3.25	0.85
Brake shafts	2.00	1.40
Rear housing tubes	85.00	3.90
Steering worms	28.00	2.60
Universal joint yokes	9.00	1.80

of $341.75 in addition to the assurance of longer life and a true fit. No wonder the local sales manager of the truck company supplying the oil company with their trucks could say to the superintendent of the garage, "You cost us several thousand dollars a year in spare parts." This reaction, however, did not stop this same manager from sending his head repairman to the garage to pick up some pointers on bronze-welding as well as other repairs. Now it is fully realized that auto trucks carry heavy loads and make high speeds and it is with full realization of these two conditions that the repairs mentioned, as well as many more, are recommended. Bronze-welding has stood the test of time, for runs of 60,000 to 75,000 miles are commonly made before a bronze-welding part wears down sufficiently to make further bronze-welding necessary. Such performance speaks for itself. In rebuilding with bronze a worn part that has already been bronze-welded, it is the practice at this shop to grind off what is left of the first deposit of bronze, exposing the original base metal upon which the new deposit of bronze is then built up to the desired size. This practice is recommended.

The scrap bin of this maintenance unit has had practically no use for the past 3½ years. A metropolitan bus company told the author some months ago in answer to the question, "What use do you make of bronze-welding?" "Come on and have a look at the scrap box." In the first place it was small and, second, it contained only some small parts of fenders, bolts, nuts, etc., that even a junkman would hardly stop to consider. Notice that the term used was "scrap box," not "scrap pile." This same superintendent had a high compliment paid to him. One of the largest auto bus companies on the Pacific coast sent an engineer clear across the country to find out how this superintendent could maintain buses on a nickel fare and make it pay, while they couldn't do it on a dime fare. Other things than bronze-welding naturally entered into this circumstance, but bronze-welding reclamation was certainly one of the most important factors in the low maintenance costs established by this company.

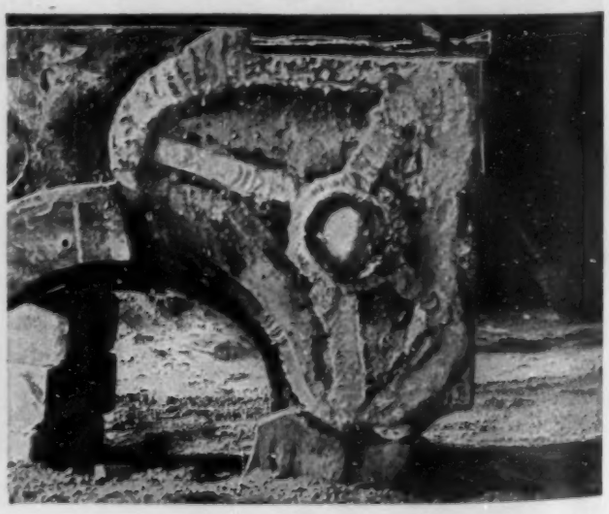
Oil companies have found it more expedient, cheaper and better to reclaim leaking galvanized or black iron oil drums by bronze-welding than by other methods. It should be noted that, in such reclamation work, careful attention should be given to the safe practices which should be observed at all times in repairing containers that have been used to carry gasoline, oil or other flammable materials. Before welding, the drums must be thoroughly cleaned with live steam or strong caustic soda solution and, wherever possible, the container should be filled with water and properly vented before welding is started.

Acid-resistant bronzes are made by many brass foundries and some foundries specialize on wear-resistant bronzes. Both types are reclaimable.

In the coal mine regions particularly, the corrosiveness of the water is well known and a vital factor in maintenance, hence, a lot of bronze parts are used—for instance, water meters, regulators, impellers, etc. Practically all of these require machining. Machining often uncovers sand holes and other flaws. A company selling such a product has, of course, to be more careful of appearance than one reclaiming a part which is their own property. Therefore, in any welding of this nature the weld metal color must match the original and there must be no blowholes in the weld on subsequent machining. By use of the oxidizing flame and the proper bronze-welding rod these particular problems have been overcome. One such foundry in particular reclaims quite a percentage of what otherwise would be high-priced bronze scrap—"high priced" because the machining is often much more expensive than the bronze itself.

Cast-iron foundries have for several years made extensive use of bronze-welding in repair and maintenance, and everyone has seen views of the larger pieces of equipment, such as pipe flasks, bathtub flasks, permanent molds, etc. Now an automotive piston ring isn't very big and neither are the flasks in which cast-iron rings are cast. A 6-mold flask costs only about a dollar. They are rather fragile and it would hardly seem to pay to reclaim these by bronze-welding. But with an average repair cost of 8¢ it does pay, and when an operator can, and does, readily reclaim 150 per day,

Fig. 4—Badly Fractured Trunnion-Bearing Block Supporting Huge 290-Ft. Cement Kiln Repaired by Bronze-Welding



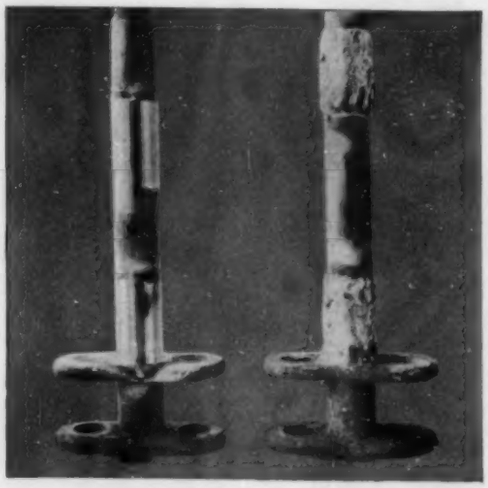


Fig. 5—Truck Brake Shaft (Right) Bronze-Surfaced at Points of Wear and a Similar Shaft (Left) after Bronze Welds Were Machined. Time for Job, One Hour

the capital investment in equipment is kept down.

A manufacturer of cast-iron electric outlet boxes formerly had a huge inventory made necessary so as to satisfy the peculiar needs of different parts of the country. By altering the base design he was able to attach outlets by bronze-welding as desired and lowered his over-all cost and his inventory.

Quite recently a manufacturer of cast-iron kitchen ranges was able to take an order profitably only because he was able to take advantage of bronze-welding. He had on hand a stock of earlier model ranges. His prospective purchaser would have been satisfied with these except for the fact he desired an additional fixture. Bronze-welding enabled the range manufacturer to put the bracket where it was wanted and he got the order.

These examples indicate ingenuity in the use of bronze-welding and serve to illustrate that small individual savings may in the aggregate loom large at the end of a fiscal year.

A brick press frame developed a fracture 3 ft. long. To replace the frame would have cost about $1000. Instead the break was chipped out on both sides and ground. A $\frac{1}{2}$-in. hole was drilled at the end of the crack to prevent it from spreading. Two welders, one on either side of the frame, after locally preheating the area slightly with the welding blowpipe, applied 25 lb. of bronze over the break. This involved over 24 in. of horizontal welding and 12 in. of overhead welding. To prevent damage to some bearings near enough to the heat zone to be possibly affected, cold water was poured over the bearings at frequent intervals. No machining was found necessary after the job cooled down. This job could not have been done in place by any other method, and the cost of the repair was insignificant.

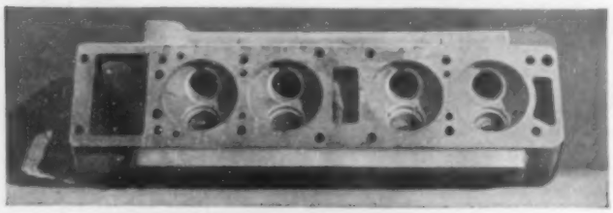


Fig. 6—Valve Seats in Cylinder Head Built Up with Thin Layer of Bronze and Reamed to Proper Size

Recently a company obtained an order for certain metal stampings. In the midst of fulfilling the order an important cast-iron draw press broke through the head. This concern believed in welding, for several years ago they had had a press break and had sent it out to be cast-iron welded. This was successful and the only drawback was they were without the press for

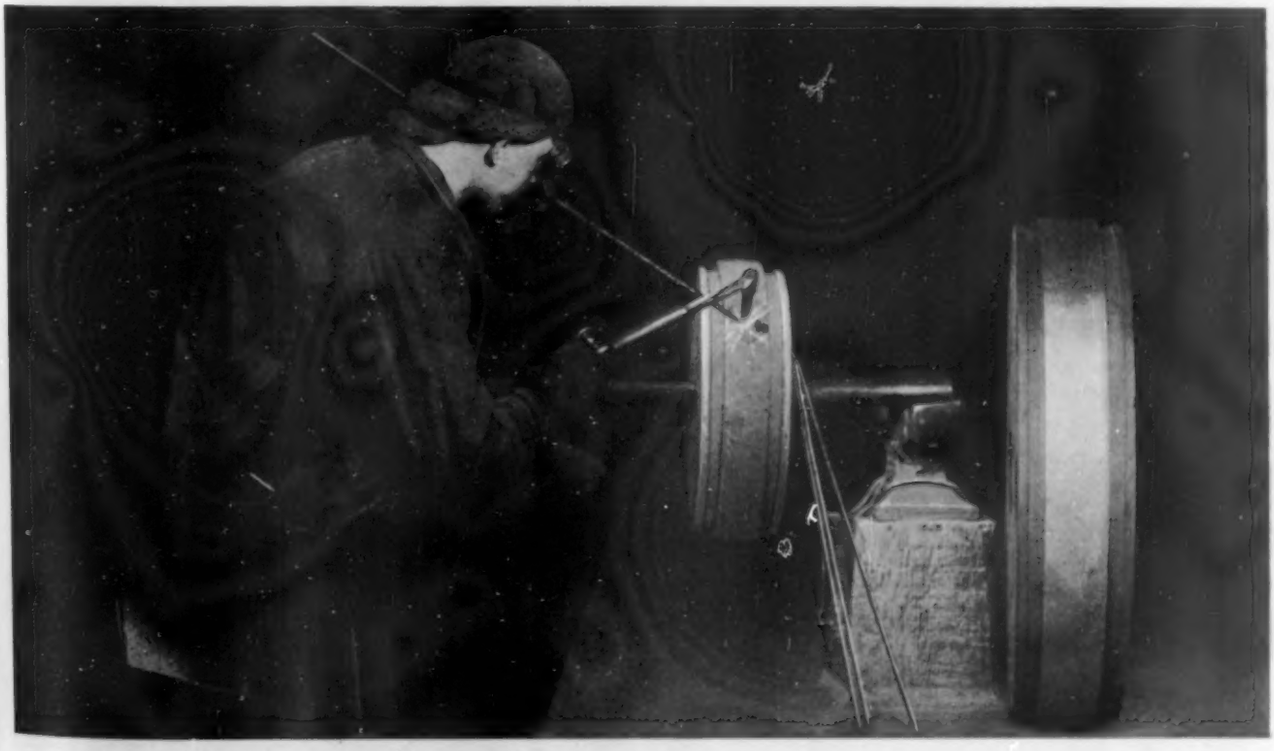


Fig. 7—Bronze-Surfacing a Steam Engine Bull Ring Which Was Subsequently Machined to Fit. This Operation Can Be Repeated Again and Again, if Necessary

Fig. 8—Bronze-Welding a Cast-Iron Steam-Jacketed Kettle at a Small Percentage of the Cost of a New Vessel

a whole week. On this recent occasion, time was the important factor. Here's what they did—the section to be welded was channeled by chipping and grinding, the broken section being 8 in. thick and 12 in. long. While the break was clean and loss in alignment was hardly noticeable, the correct alignment was secured and kept by strong backs. At 7 P.M. the same evening the job was started. A kerosene preheater warmed up the broken section, and then one welder went to work. He kept at it with but few rests until 2 A.M. The work was not allowed to cool off too much during his rest periods and the piece was protected from draft by screens. The break occurred early Friday afternoon; by Saturday afternoon the head of the press was being put back in place and on Monday morning it was back at work. The job was successful because the operator used the proper procedure. He properly prepared his work, he took advantage of the kerosene preheater, he lined his job up correctly, he worked on clean metal, he protected the heated job from sudden drafts of cold air, he let it cool slowly and he used good welding material. Thus, we have a procedure control, that is, the application of good mechanical horse-sense plus skill and proper technique to a welding job.

It would indeed be remiss not to mention that the use of bronze-welding is finding more and more favor for making joints in galvanized pipe. Recently on some Federal Government work in Washington, D. C., the government inspectors were pleasantly surprised to see the tests of bronze-welded pipe: tensile tests that did not fail in the weld; free-bends that bent double without failure; and minimum loss to the galvanized surface. They gave bronze-welding their O.K. and its use is proceeding right now on the extensive Federal buildings at present in process of construction.

It would be possible to cite similar examples indefinitely, every one worth while, every one trustworthy and every one standing up well in the service demanded of it. Whenever a piece of equipment breaks, or alterations may be necessary, consider the possibility of using bronze-welding. If you need advice or help, the supplier of your welding gases, welding equipment or rod will be glad to give you the benefit of his experience.

The bronze-welding operation is simple. Any welding craftsman can be shown the correct application in a very short time. While bronze is strong and ductile, it won't obviate the use of common sense, so do not expect the impossible; make due allowance for contraction and expansion stresses, and if a little preheat will help, use it, although most bronze-welding can be accomplished without preheating.

In summing up, the advantages of bronze-welding for repair work may be stated as follows:

1. Almost all bronze-welding repairs can be made in place.
2. Elaborate preheating is very seldom necessary.
3. The welding bronzes used today are usually of far better material than the metals they join, are stronger and more ductile and thus better able to resist the stress that might have caused the break in the first place.
4. Bronze-weld metal is readily machinable.

Bridge Welding Practices in Australia

By W. T. B. McCORMACK

†Mr. McCormack is Chairman of the Victorian County Roads Board, Australia. (*Cuts furnished through the courtesy of the Engineering News-Record.*)

SINCE 1928 three arc-welded bridges have been built in Victoria, Australia, and welding was used for centering trusses on a high concrete structure. These bridges compare favorably in size with welded bridges built elsewhere in the world. Alternate riveted and welded designs were prepared, and in each case the lowest bid was for a welded structure. From the building of these bridges and other types of structures a successful procedure has evolved which is placing welding on a par with riveting.

In Australia practically all structural welding has employed covered electrodes. It has also been found that the desirable characteristics of welds with regard to penetration, ductility, uniformity and strength require the multiple-run system of welding. Covered electrodes of 8 and 10 gage, in lengths of 18 in., form the basis of design, with welding currents of 100 to 150 amp., depending upon the thickness of the metals to be joined. The initial run is usually of a 10-gage electrode deposited in a length of 7 to 9 in., forming a $^{3}/_{16}$-in. triangular fillet. Where greater strength is required, additional runs are made. The standards for maximum fillets are shown in the accompanying table. Definite strengths being obtainable from the combinations of multiple runs, no attempt is made to specify fillet size. Although there have been attempts lately to introduce fillet size as a standard of measurement, it has not been found essential nor desirable. If a weld fillet is specified by size, the psychological effect upon the welder is to build up quickly with heavy runs, whereas greater benefits at no extra cost are obtained by a larger number of runs.

Welding costs about one shilling per ft. of $^{3}/_{16}$-in. fillet. The ratio of cost to strength provided increases very rapidly with large fillets and is three times as high for a $^{3}/_{4}$-in. fillet as for a $^{3}/_{16}$-in. fillet. Therefore, it is more economical to use a greater length of small fillet. Furthermore, large fillets generally are not economical as it is considered essential to weld plates all around the joints to prevent rusting between them. The loads

Standards for Welding Design, Victoria, Australia

Plate Thickness, In.	No. of Runs	Size of Electrode, S.W.G.	Current, Amp.	Length of Run per Electrode, In.	Ft. of Electrode per Ft. of Welding	Ult. Strength, Tons per Lin. In. of Welding, End Welds	Side Welds
1/16	1	14	55	15	1.2	1.0	0.6
1/8	1 or 1	12	75	13	1.4	2.0	1.9
		10	100	18	1.0		
5/16	1	10	100	13	1.4	3.0	2.2
1/4	1	10	100	9	2.0	4.0	2.8
5/16	2	10	100	9	4.0	4.8	3.4
3/8	3	10	100	9	6.0	5.6	4.0
1/2	1 + 2	10	100	9	2.0	7.2	5.2
		8	125	8	5.0		
5/8	1 + 4	10	105	9	2.0	9.0	6.4
		8	130	9	8.0		
3/4	1 + 5	10	105	9	2.0	10.4	7.2
		8	130	8	11.0		

in members of highway bridges being relatively small, large fillets are seldom necessary. Where reasonable fillet sizes cannot provide the necessary strength, the end of the member may be sawtoothed to increase the length of weld.

Pykes Creek Bridge

Of the four bridges erected to date, the first was designed in 1928 and constructed in 1929. It is not a welded bridge in the strict sense of the word but a reinforced concrete structure in which light welded trusses were used to support the forms, concrete and the bar reinforcing. These trusses are placed within the beam stems and comprise a part of the steel reinforcement. Their weight is 22.65 tons.

This bridge, known as the Pykes Creek Bridge, is 246 ft. long and 28 ft. wide between parapets. The length is made up of two 40-ft. end spans, two 54 1/2-ft. intermediate spans and a 56 1/2-ft. center span. The bridge crosses a deep ravine that is part of a water-storage reservoir and is 90 ft. high to the roadway. Foundations are on rock, and the superstructure is continuous with variable moments of inertia. Figure 1 shows the completed trusses in position, ready for the pouring of the concrete.

Sunday Creek Bridge

The Sunday Creek Bridge, designed and constructed in 1930, is also founded on rock and is a continuous steel truss carrying a concrete deck 22 ft. wide, Fig. 2. Spans are 52 ft. at the ends and 65 ft. for the two central spans, which arrangement gives approximately equal positive moments in all spans and equal negative moments at the piers. Abutment supports are on rollers. Three lines of trusses are used. Chords consist of pairs of angles separated 6 in., permitting 8 x 6, 6 x 5 and 6 x 3-in. I-sections to be used as verticals. Except where stress reversals occur, the inclined web members are pairs of flats welded to the outside of the chord angles. The trusses were shop-fabricated in lengths of 30 to 35 ft. and field-spliced at about the quarter points. These splices were made by means of turned bolts driven into reamed holes, although it is now recognized that a field-welding plant would have made splices more economically. The total weight of structural steel in the bridge was 48 3/4 tons.

Swan Reach Bridge

Designed and constructed in 1931, the Swan Reach Bridge is a structure with a total length of 406 ft. made up of six welded plate-girder spans of 62 ft. and a central span of 43 ft. Rolled beams were used in the central span, and it is designed as a future lift span, Fig. 3. Foundations are piles driven into silt. Each section of three spans, in the length of 186 ft. each side of the lift span, consists of cantilevered plate girders and a suspended span of 34 ft.

In this bridge, as in the Pykes Creek Bridge, the slab is constructed as a vehicular deck 27 ft. wide, including a 5-ft. wide gravel side walk held between an outer curb and a concrete curb cast on the deck. This arrangement gives flexibility of roadway width at little extra cost.

The details of the welded plate-girder section and the cantilever-suspended-span junction are shown in Fig. 4. Flange angles are eliminated. Stiffeners are flats welded intermittently on both sides to the web plate and solidly at the ends to the flange plates. At the suspended-span junction the leg of the angle paralleled with the girder web was hand-dressed to a radius of 36 in. and supported on a corresponding leg-dressed flat, with a strip of brass 1/8 in. thick separating the two angles.

The total weight of welded steel in the bridge was 101 tons. A total of 16,000 ft. of welding was used, consisting of one run of 10-gage electrode 18 in. long deposited in 9 in. and known as 10/9.

Snowy River Bridge

The Snowy River Bridge, designed in 1931 and constructed in 1932, is situated on a mountain road 95 miles

Fig. 1—Welded Trusses in Pykes Creek Bridge Used to Support Forms for Concrete Ribs and to Supplement the Rod Reinforcing

Fig. 2—Four-Span Continuous Welded Truss Bridge over Sunday Creek. Chords of Trusses Are Two Channels Spread Apart to Permit Insertion of 6-In. Wide I-Sections as Vertical Members. Diagonals Are Flat Bars

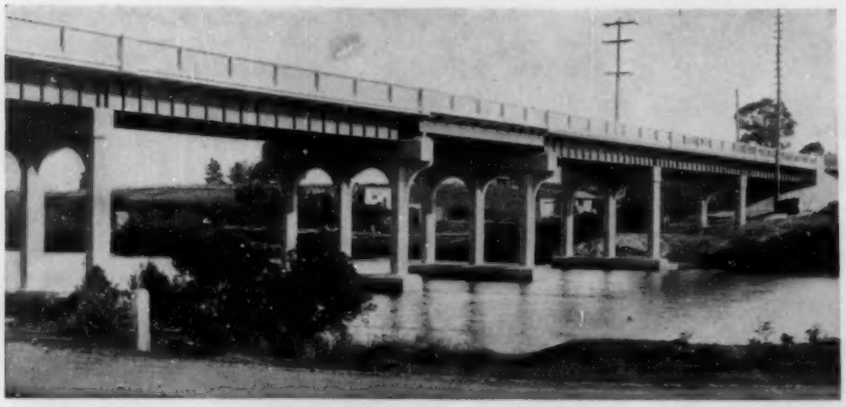


Fig. 3—Welded Plate-Girder Bridge over Swan Reach. Short Center Span of Rolled Beams Is Planned for a Future Lift Span. Three Spans Either Side of This Center Span Are Designed as Cantilevers with a Suspended Span in the Center

Fig. 4—Junction of Cantilever and Suspended Spans on Swan Reach Plate-Girder Bridge (Right)

from the nearest seaport and is without railway facilities. It was built essentially for livestock (cattle and sheep), but will safely carry a 10-ton vehicle. The live load was assumed at 100 lb. per sq. ft., plus 30 per cent impact. The total length of the bridge is 750 ft., and the average height from deck level to stream-bed level is 56 ft.

There are two end spans of 105 ft. and four intermediate spans of 135 ft. The trusses were made continuous throughout, with a fixed connection on the center pier and rollers on the other piers and the abutments. Truss fabrication and erection were necessarily done at the site, each span being assembled under its final position.

The welding plant consisted of a gasoline-driven three-phase generator and three welding sets. The maximum length of members possible to transport over the road (12 per cent grades and 20-ft. radius curves) was 40 ft.

Trusses were built up almost entirely of channels except for minor bracing, for which angles were used. The trusses are Warren, deck-type, 10 ft. deep and set 10 ft. apart on centers. Panels are 15 ft. long. Chords, consisting of pairs of channels $12^1/_8$ in. clear between webs with flanges turned out, are 10 in. x 24.46 lb. at the piers and 9 in. x 17.46 lb. toward the center of the lower chord. Web members are pairs of channels with flanges turned in, fitted between the chord channels and welded directly to them. Compression sections were laced with $2 \times {}^5/_{16}$-in. and $2^1/_2 \times {}^5/_{16}$-in. straps, which were welded to the channels.

The trusses were erected as simple spans. To put in the proper dead-load stress for continuous truss conditions, the splices between the trusses on the piers were made by placing a hinge in the bottom chord and by pulling the top chords together with a tension of about 40,000 lb. per truss. The tension was applied with screwed $1^1/_4$-in. diameter rods, and nuts were placed between temporary pieces connecting the top-chord channels. The rods were calibrated for elasticity, and the tension was determined by extensometer. The total weight of steel was 132.7 tons. A total of 20,328 lin. ft. of welding was applied, consisting of one run of 10-gage electrode deposited in 9 in. and one run of 8-gage electrode deposited in 8 in. The minimum weld run was a single 10/9, and the maximum was 10/9 plus 2 at 8/8. The bridge during construction is shown in Fig. 5.

Organization

The bridges were built by the Victorian County road board by contract from funds raised on vehicle and gasoline taxes. Construction was under the general direction of Louis F. Loder, chief engineer for the board. The designs were prepared and the construction work was supervised under the direction of Marsden G. Dempster, bridge engineer.

Fig. 5—Snowy River Bridge, Good for 10-Ton Vehicles, Comprises Two Spans of 105 Ft. and Four of 135 Ft. Trusses Are 10 Ft. Deep, 10 Ft. Apart and Designed as Continuous with a Fixed Bearing on Center Pier

Arc Welding Helps Solve Problem of Under Water Structure for New San Francisco Bridge

By A. F. DAVIS

†Mr. Davis is Vice-President of the Lincoln Electric Company.

SETTING a new record for depth below water, the arc welding of cutting edges and caissons for the San Francisco open bridge represents one of the outstanding engineering feats of the year. The center anchorage of this bridge is 197 ft. long, 92 ft. wide and, when placed, will be 237 ft. from the lower cutting edge to the top. This is the greatest depth below water in which man has ever attempted to work.

The first cutting edge to be completed was 127 ft. by 92 ft. (see Fig. 1). This cutting edge is built up of $^{3}/_{8}$-in. steel plate welded to and around angle iron frames. The plates are first brought to their proper dimensions by arc welding two or more sheets together. This operation is a continuous butt weld made from two sides. The plate is set in position for welding, allowing a $^{5}/_{32}$-in. gap with no bevel. The second bead on the reverse side fusing into the first bead makes a perfectly sound joint. Such a joint eliminates planing a bevel and permits higher welding currents to be used, with resultant higher speeds.

These plates are tack welded to the angle iron frames using 2 in. of $^{3}/_{8}$-in. fillet welds spaced 6 in. apart and staggered on the opposite side of the angle frames or stiffeners. A complete cutting edge section is shown in Fig. 2. The section is set in an upright position on a $^{3}/_{4}$-in. keel plate, as shown in Fig. 3. Figure 4 shows the inside of the same section before it is drawn up to the adjoining section.

The rectangular double walled outer shell is then divided into sections 15 ft. square. These dividing members or box struts are also completely fabricated by arc welding. Figure 5 shows the placing of these box struts in position. Welds are made in vertical position at the intersecting points of the box struts and also at the joint on the inner wall of the cutting edge sections.

Fig. 7—Arc-Welded Cutting Edge with 55 Squares. The Weight When Completed Will Be 900 Long Tons

Fig. 8—Adaptor Sections in the Process of Fabrication with the Electric Arc

Fig. 1—The First Cutting Edge to Be Completed for the San Francisco Open Bridge

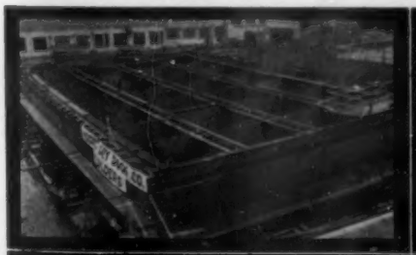


Fig. 2—The 6-Ton Section for the Cutting Edge

Fig. 3—Section Placed Upright on ¾-In. Keel Plate

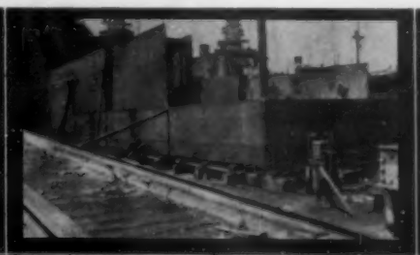


Fig. 4—Inside of Section Shown in Fig. 3 before Being Drawn up to the Adjoining Section

Fig. 5—Welded Box Struts Being Placed in Position

Fig. 6—After Launching Adaptor Sections Are Welded into the Top Section

Horizontal welds are made where the cutting edge section joins a 3/4-in. keel plate on the outer wall. The inner wall plate is brought up to the bottom of the outer wall plate, forming a knife or cutting edge. A weld is made at this point. A heavy plate carrying jets is riveted along the bottom. Water is forced through these jets at high pressure in order to wash away the mud while the section is being lowered through the muck to its final position at bed rock.

After all seams have been welded water tight, this first cutting edge is slid down the ways to make way for the fabrication of the next cutting edge.

After launching, adaptor sections, 15 ft. square in one end to 15 ft. in diameter on the other end, are welded onto the top of each square section, as shown in Fig. 6. To the round top of each of these adaptors an arc-welded caisson 15 ft. in diameter is welded. The whole structure is brought to about 60 ft. in height in the yards, after which it is towed to position in the bay. Concrete is poured into the double walls of the cutting edge in box strut sections. As it sinks, side walls and round caissons will be welded one on top of the other until the structure reaches a high tide level. In the case of this first cutting edge this will be 202 ft.

The first cutting edge is divided into 28 square sections and its weight is about 425 long tons. The large cutting edge shown in Fig. 7 is divided into 55 squares and its weight, when ready for launching, will be 900 long tons.

Figure 8 shows operators fabricating adaptor sections. These sections are also 3/8-in. plate completely arc welded.

The Moore Drydock Company has the contract for the fabrication of all ten of the cutting edges required. Welding is being done by the shielded arc process using our covered electrodes. Welding is done in accordance with the rigid welding code of the State of California. The code requires a minimum tensile strength of 65,000 lb. per sq. in. and minimum ductility of 18% elongation. All operators were required to submit three samples made in down, vertical and overhead positions, meeting the requirements mentioned above.

Using Arc Welding to Save Weight in Bascule Bridge Reconstruction

By A. G. BISSELL

†Mr. Bissell is Consulting Arc-Welding Engineer, Seattle, Washington.

A NEW departure in bridge-floor construction that has attracted considerable attention throughout the country, is the use of an open grating flooring, used in the widening and reconstruction of the bascule span of the University Bridge, Seattle, Washington. The use of this novel floor construction has, more or less, overshadowed the fact that in adding two additional 8-ft., 10-in. roadways to the original 40-ft. roadway of this bridge nearly all of the material added to the bascule span was of arc-welded construction.

The University Bridge, crossing an arm of Lake Union and the Lake Washington Ship Canal, was completed in 1919. At the time of its completion, the bascule span and its foundations were of permanent construction; however, the approaches, about 200 ft. on the south and about 975 ft. on the north, were of temporary timber and piling construction as shown in Fig. 1.

The bascule span has two 101-ft. leaves which originally carried a roadway and two street car tracks between the trusses and a sidewalk on each side outside of the trusses. The roadway, 40 ft. wide, was constructed of planks upon which were laid creosoted wooden blocks. The sidewalk was planked.

During the 12 years that this bridge was in service, two changes were taking place. Traffic was steadily increasing from 6700 cars in 1919 to 34,000 in 1930 per 15-hr. day and at the same time the temporary approaches were deteriorating and presenting a continuous fire hazard. These facts demanded that permanent approaches should be constructed and that both approaches and bridge proper be made to carry the increased traffic without congestion.

The new approaches were designed with a roadway width of 58 ft. which was about 18 ft. wider than the original roadway of the bascule span which occupied the entire space between the trusses. This demanded that more roadway be provided on the span to handle the increased capacity of the approaches. As it was not practical to widen the span roadway by increasing the distance between the trusses and undesirable to install a second bascule because of the excessive expense, the only other alternative left was to place the additional roadway space on each side of the span outside of the trusses.

Let us remove the original sidewalk planking and see what would be required to put a roadway in its place. The old sidewalk was supported by brackets riveted to the vertical members of the trusses. It does not seem

Fig. 1—Original Bridge with Temporary Approaches

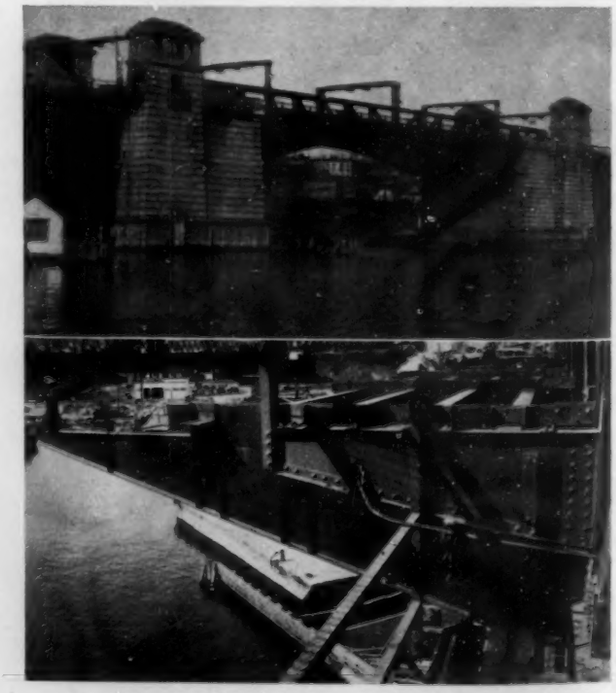


Fig. 2—New Arc-Welded Bracket and Old Sidewalk Bracket

Fig. 3—Riveted Brackets on New Approach

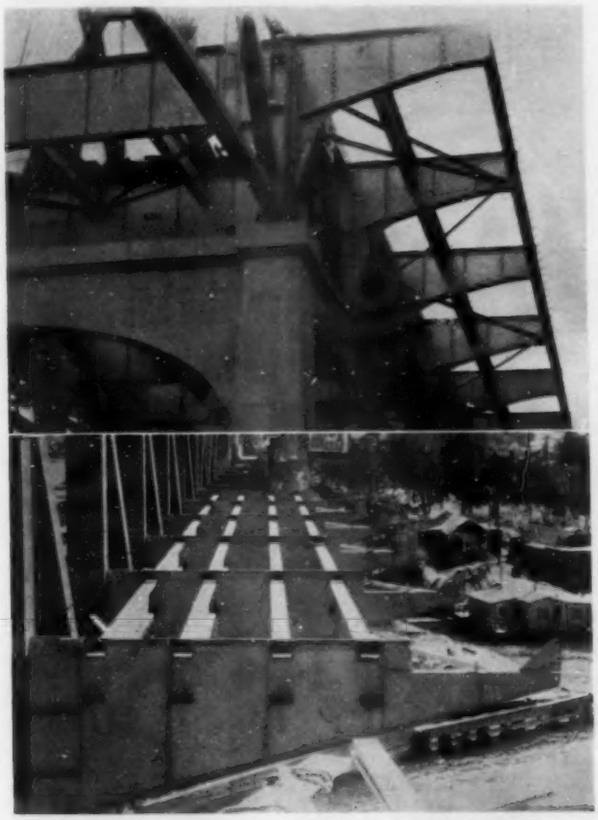


Fig. 4—Arc-Welded Brackets with Stringers in Place

unreasonable to believe that these 4-ft., 8-in. brackets could be replaced by others of sufficient width and strength to carry a 8-ft., 10-in. roadway and a 4-ft., 8-in. sidewalk. New brackets could be easily fabricated, the old ones cut off and these new ones riveted into place. Of course, the new brackets would be deeper and heavier but they could be installed. Stringers could be riveted to the new brackets and a new roadway planked in and resurfaced. However, we have been overlooking a very important fact in bascule bridge construction. It must be remembered that the leaves of a bascule bridge must be so perfectly counterbalanced that the operating apparatus has but to overcome friction, windage and snow loads to open and close the bridge. Therefore, for every pound of material attached to the leaves in excess of material removed, there must be added about 2 lb. to the counterweight. Computations quickly showed that to widen and rebuild the bridge as we have outlined above, would increase the dead load so much that there would not be sufficient room in the counterweight space to add the required balancing material, also the trunnions and main members of the span would be loaded past the safety limit. Hence, it became necessary to find some lighter form of construction to fabricate these parts and other means to reduce the weight on the leaves of the span.

Mr. J. A. Dunford, who was in charge of the work of rebuilding the bascule, has for many years used arc welding as a means of making replacements and repairs on Seattle's many bascule spans. So it was perfectly natural that he should turn to the use of arc-welded fabrication to construct the required roadway brackets at a minimum weight. Besides fabricating these brackcet, arc welding was used to obtain continuous stringers, stiffen floor beams, eliminate riveted connections, castings, etc., always with one point in view—to get lighter construction.

It will be noticed in the work on this bridge, as in the early stages of arc-welded building construction, that riveting has not been entirely replaced. This was due to the nature of the job, the presence of old rivet holes where original members were removed which were used in bolting up the new members and the tendency of the designer, more familiar with riveting practice, to use that process in critical locations until such time as he has gained full confidence in the new process.

The brackets (28 being required) were all very much alike except for the number and location of the stiffeners; and in some cases the stringers pass through the webs, while in others only the continuity bars pass through the webs. Figure 2 gives a general idea of the new bracket as compared with the original sidewalk bracket. A comparison of the weights of this arc-welded bracket with the old sidewalk bracket and the riveted bracket used on the approaches is quite interesting. The small bracket used to carry only the sidewalk and railing load, weighed around 530 lb., while the new one designed to carry the new roadway and traffic up to a 20-ton truck and a 50% impact load, weighs only about 1300 lb. The riveted brackets used on the approach are shown in Fig. 3. While these brackets were designed for the same live load, the dead load is much more than on the span. However, it is interesting to note that to carry the same traffic, the designers of the widened bascule span, by reducing their dead load and using arc-welded construction, use a 1300-lb. bracket where a bracket of over 4000 lb. is used on the approaches.

Fig. 5—Upper Continuity Bars on Stringers

Fig. 6—Floor Beams and Cross-Bridge Tie Bar

Note that on the riveted approach bracket 6-in. x 6-in. x $^{5}/_{8}$-in. angles are used for top and bottom flanges which weigh more than the entire welded bracket. The liners or fills under the angle stiffeners of this bracket run over 300 lb. and add nothing to the efficiency of the stiffeners. However, there was no demand to save weight on this section of the bridge.

In the construction of these welded brackets every effort was made to keep the weight at a minimum. It can be seen in Fig. 4 that the $^{3}/_{8}$-in. lower flange which is welded to the $^{5}/_{16}$-in. web plate, instead of being of uniform width for its entire length as is customary in usual construction, tapers from 9 in. at the inner end to 3 in. at the outer end without reducing its effectiveness, but reducing its weight about 25%. Instead of a top flange, two tapered straps, one on each side, are welded to the top edge of the web forming a reinforcement to carry the floor and resist vertical bending and also to serve as a tension member which passes through the vertical truss member, crosses the main part of the bridge and connects to a similar member on the opposite bracket. These top reinforcements are $^{5}/_{16}$-in. straps tapered from 6 in. to $2^{1}/_{2}$ in. in width. Lateral stiffness of the brackets is obtained from the stringers and diagonal braces which can be seen in Fig. 4.

It can be seen that the connections between the reinforcing strap and the cross-bridge tie are riveted as are all the joints in these tie members. This is one of the critical points mentioned above where rivets were retained because of the greater familiarity of the designer with this form of construction. It is believed that this mixed construction will disappear in future work.

The bracket stiffeners are $^{3}/_{8}$-in. flat bars whose depth corresponds to the width of the lower flange at the point of their connection. On the inboard edge of the brackets it can be seen that a $^{3}/_{8}$-in. x $9^{1}/_{2}$-in. plate is welded to the web to form an end flange. This flange is punched to match the rivet holes of the old bracket and is riveted to the vertical truss member. It was felt that this was the simplest method of attaching these brackets. In some instances the flange does not extend the full depth of the bracket web. In these places the web is welded directly to the truss member. Figure 4 also shows the small shelf brackets on the web upon which the stringers are landed. They are formed by a $^{3}/_{8}$-in. plate which is passed through the web and braced on each side by a triangular $^{3}/_{8}$-in. plate, all welded together. Above these small brackets can be seen narrow slots in the web. These are to pass the stringer, top continuity plates.

When the stringers were first placed, they were secured by two bolts at each end to the brackets just described. Later, these bolts were replaced by rivets. This procedure, however, was unnecessary as the stringers were welded to the shelf bracket plates which pass through the web to make the lower stringer flanges continuous. To obtain the same results with the upper flanges two $^{5}/_{8}$-in. x 3-in. x 13-in. flat bars were passed through the slots in the web at the upper flanges and welded to them. The two bars were used in order that more weld metal could be put in shear than would have been possible with one bar 6 in. wide. A close view of this connection is shown in Fig. 5. The stringers were made of 14-in. beams weighing 33 lb. per foot. Had continuous construction not been used in these stringers, it would have been necessary to have used 14-in. beams weighing 42 lb. per ft.

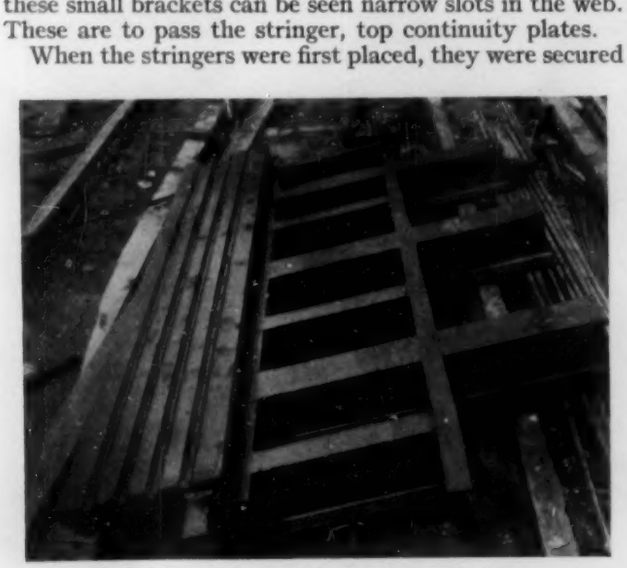


Fig. 7—Fabricated Unit for Floor Break

Fig. 8—Irving Grating Roadway, Curb and New Railing

Fig. 9—Traffic Barrier Portal

On these stringers are placed 6-in. x 8.2-lb. channel floor beams having a $^{1}/_{4}$-in. x $1^{3}/_{4}$-in. stiffener welded in above each stringer as shown in Fig. 6. It will be seen that in two positions, two stiffeners are present above a a stringer. The beams will be notched out at these locations to correspond to the heavy tie bar in the foreground to pass the rails of the street car track. By using these stiffeners over the stringers, it was possible to use the 6-in. x 8.2-lb. channel instead of a 6-in. x 13-lb. channel. The floor beams are secured to the stringers by 3-in. fillet welds at the heel and toe of the channel.

In the foreground of this view can be seen the 1-in. x 6-in. tie bar that connects the top members of opposite brackets. Note the method of reinforcing the cut to pass the street car rail by welding a 1-in. x 3-in. bar on each

side just below the cut, thus retaining the full section of the tie bar at the notch. Such an application can be done economically only by welding.

At the breaks in the floor of the original bridge were castings. Because of foundry requirements, these castings were made up in 4-ft. lengths which were bolted together to form the sections required. On the new sections of the bridge these castings were replaced by fabricated sections made up to the required lengths in an integral unit. The over-all construction is shown in Fig. 7. The plates and shapes were welded together to give a unit that fits into the general form of the other members. The four lighter beams land on and are welded to the stringers that pass through the web of the last bracket and the three heavier members butt against and are welded to the upper reinforcing bar of the bracket. As no patterns, core boxes or machining were required, these pieces were less costly than corresponding castings.

With the brackets, stringers, floor beams and break members in place, we must find a light-weight surfacing material with which to floor the bridge. To return to the original plank and wooden block roadway would mean the addition of too great a load to the leaves. Battledeck flooring was suggested but the idea was abandoned in favor of Irving open grating. Irving grating filled in with asphalt had been successfully used on another bridge. The asphalt fill being just shy of the upper edge of the steel gave a very good anti-skid surface. However, on this bridge it was decided to make a radical departure and leave the grating open as shown in Fig. 8. This has the advantage of saving the weight of the filling material and allowing any accumulation of dirt or snow to pass through, thus keeping the weights of the leaves constant. The grating is attached to the floor beams at 10-in. intervals by a lug riveted to the grating and welded to the floor beam. The riveted connection is expected to give a slight flexibility to the connection and allow easy removal of the grating in case repairs are needed. The original idea was to use an angle clip and bolt the grating to the floor beams. By welding, the weight of the bolt and one leg of the clip angle was saved, as well as the expense of drilling the floor beams and swinging scaffolding below the floor. This type of flooring saved about 16 lb. per sq. ft. over the former plank and wooden block floor. This saving amounted to about 127,000 lb. on the bascule span.

The railing of the original span was of wire mesh. While effective, it was not very ornamental and was a continuous source of annoyance due to corrosion. The many lapping wires and pockets in which moisture could gather caused the railing to rust out rapidly and require frequent attention. The new railing shown in Fig. 8 was fabricated by arc welding. A 3-in. pipe forms the top rail. Attached to this pipe for its full length is a $\frac{1}{4}$-in. x $2\frac{1}{2}$-in. flat bar. The vertical members are $\frac{1}{4}$ x $2\frac{1}{2}$-in. bars, as are the scrolls. Two $\frac{1}{4}$-in. x 2-in. x $2\frac{1}{2}$-in. angles which are slotted to pass the vertical members form the two lower longitudinal members. All the joints between these members are arc welded except the single riveted joint securing the top of the scroll which was installed to give an artistic finish. The end connections were riveted to allow easy removal of any section. This railing has a massive appearance but in reality is of quite light weight. As a protection to pedestrians and to keep cars from crashing the rail and going overboard, there is an 8-in. wooden curb topped by a 7-in. bulb angle which is clearly shown in Fig. 8.

The protection girders are fabricated by arc welding and present a smooth, pleasing appearance giving a light-weight structure of greater strength than if otherwise constructed. In the same view it will be noticed that the reinforcing steel is secured to the buckle plates by means of a welded lug. It is expected that this construction will give additional stiffness to the buckle plates because a positive tie is made between the concrete and the buckle plates.

Figure 9, showing the traffic barrier portal, illustrates the result of using arc welding in the artistic development of a structure. The smooth surfaces free from projecting rivet heads, besides being pleasing to the eye, are easily painted and protected from corrosion.

In all of this work $\frac{1}{4}$-in. continuous fillet welds were used except in a few instances where heavier welds were necessary. Three-sixteenth in. sulcoate and lightly fluxed electrodes were used. The working values for weld metal used in welded steel building construction were used as a guide in this work. The use of a $\frac{1}{4}$-in. continuous fillet weld gave an ample factor of safety.

The operators employed on this work were required to produce standard butt weld test pieces developing an average of 52,500 lb. per sq. in. in tension with a 90° free bend. All electrode material had to pass this test also. The shop men were required to prepare flat and vertical test plates while the field welders prepared an additional test plate to prove their ability to do overhead welding. Occasionally during the progress of the work qualitative test samples were taken. Two welders did all of the shop work except the stiffeners in the floor beams which required two additional operators. Two operators completed the field work. Electric motor-driven, direct-current welding generators were used on both shop and field work.

To govern this work specifications following the usual structural welding specifications with some slight modifications were used. As an aid to both the fabrication shop and the inspection force, a set of joint designs and procedure control were added. This additional data was useful to the contractor and the inspection force in settling differences of opinion in regard to the new application of welding, and the work was completed without any appreciable difficulty with both gaining considerable knowledge about the arc-welding process as applied to this form of construction.

Even though the work on this bridge required some riveting, it is expected that the experience gained will be of much value in future work of the same nature in which, no doubt, a greater use of welding will be made. However, in this particular case it was responsible for reducing the weight of the added material and, it is believed, foreshadows a more extensive use of arc welding in the future and points to a more economical method of construction in bascule bridge design. Here was a bascule span, whose original cost was about $1,000,000, increased in size to carry one-third more traffic at an expenditure of only about $75,000. Thus, where space and funds are limited, it is an advantage to use arc-welded construction.

Use of Shielded Carbon Arc in Class I Welding

By E. W. P. SMITH

✦Paper to be presented at Fall Meeting, A.W.S., Detroit, Oct. 2nd to 6th, by E. W. P. Smith, Consulting Engineer of The Lincoln Electric Company.

COMPETENT designers who recognized the possibilities of welding early in its development, offered certain objections to it and the resultant weld metal. The equipment manufacturers did a great deal of work and investigation to get the correct answer to this question of the designer. Automatic welding was a laboratory experiment at the start, but in a very short time it became the accepted method of fabricating certain types of equipment such as tanks, pipe, boilers, etc. Where production is sufficient in amount, and of relatively uniform character, it shows very low costs; and the quality of the deposited weld metal is even higher than that demanded by the designing engineers.

These high quality welds and low cost of welding are the results of the development of the shielded carbon arc process.

What the Shielded Carbon Arc Is

The electric arc is normally rather difficult to control. It sets up its own magnetic field; and the passage of the welding current through the parts being welded sets up other fields. The result is the arc is sprayed out and has a tendency to wander. Its general appearance is shown in Fig. 1 and the corresponding photograph, Figure 2. Note the spread of the arc stream. The tendency is to heat too great an expanse of metal, thus wasting some energy. This spread of heat means that for a given set-up the speed must be reduced so as to put into the joint at the proper point enough heat to melt the plates. If a strong magnetic field is placed in the proper position in reference to the arc, the arc stream is focused, concentrated or localized directly beneath the carbon, and this concentration permits an increase in speed over conditions as shown in Fig. 1. Figure 3 and the photograph, Figure 4, show this directed arc stream when the magnetic field is used. There is in addition to this concentrating of the arc stream a certain amount of agitation of the molten weld metal.

Fig. 2—Carbon Arc—No Magnetic Field—No Shield

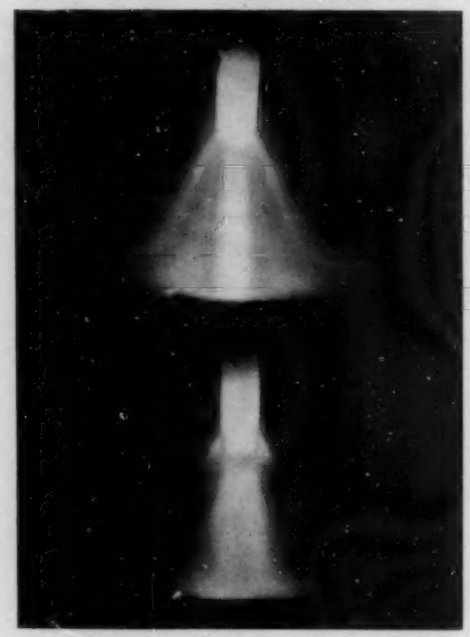


Fig. 4—Carbon Arc—Magnetic Field Superimposed —No Shield

The shielded carbon arc process automatically strikes the arc, automatically feeds the carbon electrode, autogenizer and filler strip where needed, maintains a constant arc length and rotates the carbon electrode so as to keep it symmetrically pointed.

It is evident that the weld metal under conditions as shown above would be subject to action of the atmosphere and would, therefore, be irregular in quality. To offset or eliminate this possibility, a controlled atmosphere or shield is formed around the arc and weld metal by passing against the hot carbon what is known as a fibrous autogenizer. This is chemically treated fibrous string or cord which burns as it comes in contact with the hot carbon. In so doing, it liberates gases which shield the arc and provide an oxygen and nitrogen, excluding atmosphere in which the weld metal and arc operate. Figure 5 shows the autogenizer and the shield added to Fig. 3. Note that the entire process is bathed in a controlled atmosphere. The photograph, Figure 6, shows the automatic head with autogenizer, carbon magnetic coil, which is concealed in the boot, out of which comes the carbon.

It may be suggested that with the carbon close to the

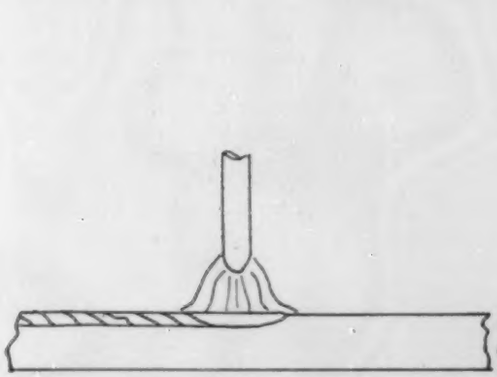


Fig. 1—Carbon Arc—No Magnetic Field— No Shield

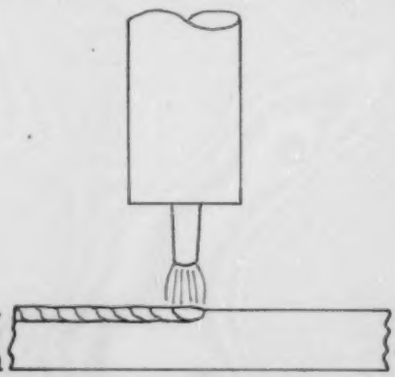


Fig. 3—Carbon Arc—Magnetic Field Superimposed—No Shield

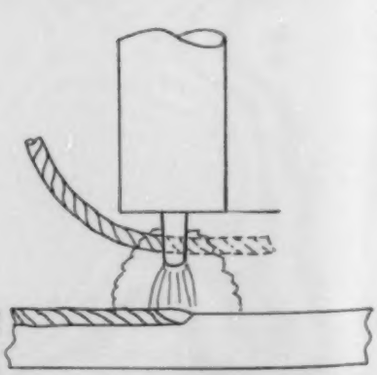


Fig. 5.—Carbon Arc—Magnetic Field Superimposed, Shielded

weld, there would be considerable carbon absorption in the weld metal. On the contrary, there is carbon removal by this process. The carbon is turned out. If metal must be added then a metal filler strip, shown in Fig. 7 and photo (Fig. 8), is used, serving the purpose of adding metal. As the metal filler strip is controlled separately from the carbon, there is, therefore, a means of adding metal at a rate determined by the conditions and not by the arc or carbon. The heat energy and the metal to be added are separate and function separately.

Note that the filler metal does not carry any current and, therefore, the usual splatter due to explosive action of a current carrying electrode is eliminated.

No preparation of the plate is necessary. Throughout the length of the seam, the abutting edges must be sufficiently close to be welded.

Figure 9 shows a typical joint—with two passes to make the joint. No weld metal has been added.

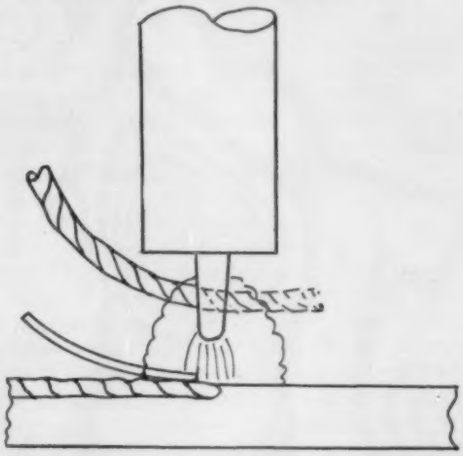


Fig. 7—Carbon Arc Magnetic Field Superimposed, Shielded—Filler Metal Added

Figure 10 shows weld metal added by filler and by inserting metal between plates, or by bending up the edges of the plate.

Note that the plate is melted and the abutting edges fused together and that, therefore, the plate forms or is used as an electrode. It is necessary, therefore, that the plate composition or weldability be considered.

Note also that plate used as an electrode costs much less than processed electrode. Knowing the analysis of the plate the proper autogenizer or flux may be specified.

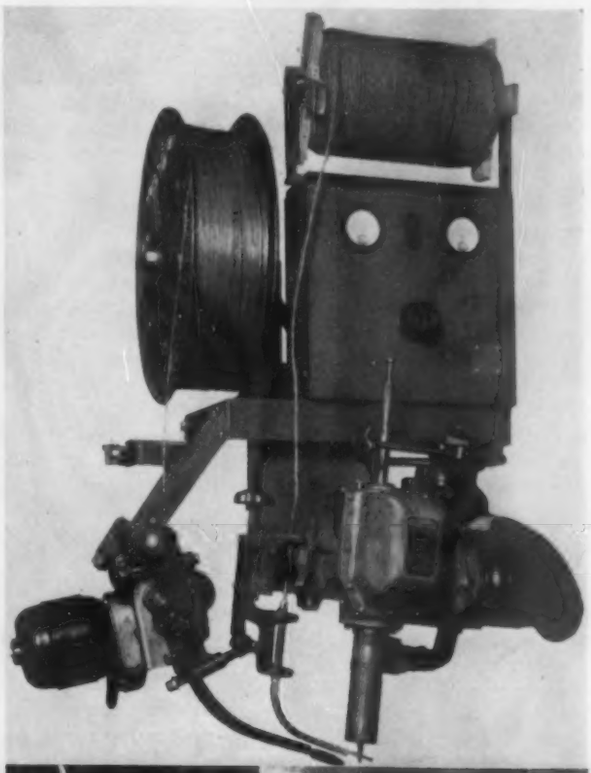
It is evident that with the simple set-up, such as outlined, high welding speeds may be obtained due to concentration of heat, automatic control of arc and ease of set-up.

Where it is possible to weld from both sides, thicknesses up to $^3/_4$ in. may be welded and a speed of 25 to 30 ft. per hr. Table A shows a few speeds for different type joints.

What the Shielded Carbon Arc Does

The elements of operation of the shielded carbon arc are, as seen, rather simple. However, the resultant weld metal, the deposited bead, possesses qualities of a very high order. The structure of the metal is excellent. The weld metal is actually better than the parent metal. This result is due, of course, to controlled atmospheric conditions. The specific gravity is 7.84 to 7.86. The A. S. M. E. code requires for Class I a minimum of 7.80 for weld metal and does not permit a retest when this value goes below 7.75. The shielded carbon arc weld

Fig. 8—Carbon Arc Magnetic Field Superimposed, Shielded—Metal Filler Added



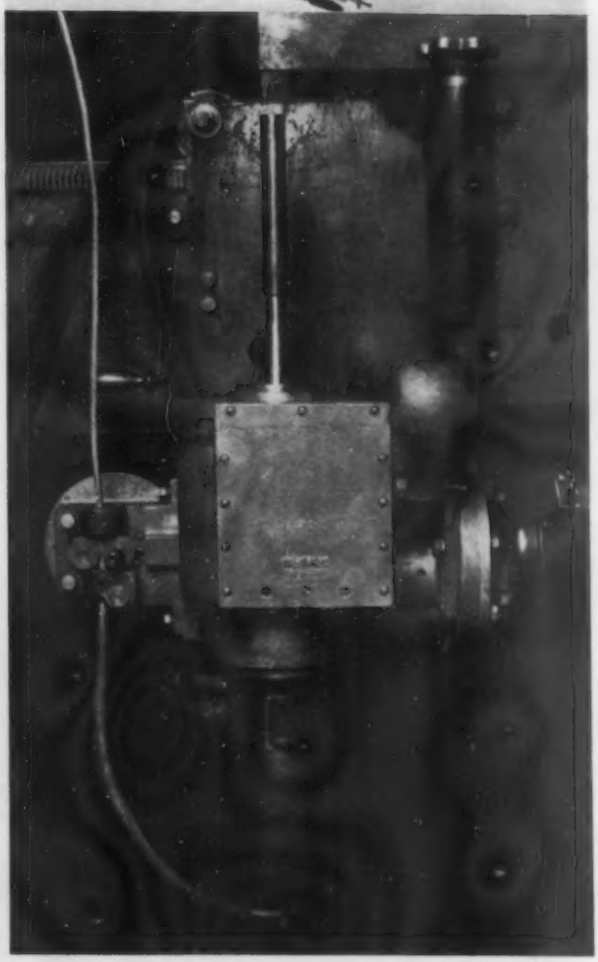
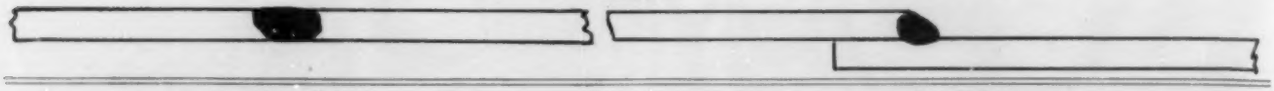


Fig. 6—Carbon Arc Head Magnetic Field Superimposed, Shielded

Table A



Butt Joints		Lap Joints	
Plate Thickness	Speed, Ft. per Hr.	Plate Thickness	Speed, Ft. Per Hr.
12 Ga	140	10 Ga	100
3/16 in	95	5/16 in	50
1/4 in	70	3/8 in	40
1/2 in	18		
3/4 in	7		

1/2-Inch and 3/4-in. plates welded from both sides. No allowance for set-up or fatigue.

No allowance for set-up or fatigue.

metal excels the code requirements by a considerable margin.

Weld metal equal to the plate in physical characteristics has been the minimum requirement of acceptable weld metal set by designers anxious to use welding as a fabricating process. High tensile strength but low ductility or high ductility, low tensile strength, has been the general or usual experience of these designers when weld metal was involved.

The development of several methods to meet these requirements has resulted in pronounced advance in welding. Shielded carbon arc gives weld metal with ultimate strengths from 65,000–76,000 lb. per sq. in., and the elongation is 20–30% in 2 in. of weld metal, a combination of values attractive to the designers. If the elongation be taken on the extreme fiber, as outside bend test, it will be 50%. Tests made on average structural steel, with ultimates in the range of 55,000 lb. per sq. in., show the elongation to be 22 to 27% in 2 in. with an elastic limit of 30,000 lb. per sq. in. This is for the plate. The corresponding test figures for weld metal for a particular test are 75,000 lb. per sq. in. ultimate, 25–30% elongation in 2 in. and elastic limit of 55,000 lb. per sq. in.

Class I welding specifies a joint efficiency of 90%. This 90% applies to the maximum allowable unit working stress in lb. per sq. in., when account is taken of the maximum temperature at which the vessel will operate, as well as the minimum specified range of tensile strength of the material. These minimum figures are from 45,000 to 75,000 lb. per sq. in., ultimate strength. Also the tensile of the weld metal must equal at least the minimum of the range of the plate. On the tests mentioned above with plate of 55,000 and weld of 75,000 ultimate, note that this is 35% more than the code requires for ultimate weld metal strength.

The same percentage overrun is true of ductility, 27% elongation as against 20% required by the code and, in the case of extreme or outside fiber, 50% elongation as against 30% code requirements. The code specifies the conditions under which these tests are to be made. Photo (Fig. 11) shows the elongation in 2 in. for weld metal only, and Fig. 12 for a specimen of free-bend test. The elongation in excess of code requirements is clearly indicated.

A desirable quality in weld metal is that it be anti-corrosion. Shielded carbon arc weld metal resists corrosion to a very high degree. Comparative tests between shielded carbon arc weld metal and non-shielded arc weld metal show very clearly the corrosion-resisting qualities of the shielded carbon arc weld metal. The shielded carbon arc shows practically no corrosion, whereas the other process shows considerable action after both have been treated under the same conditions.

After the joint has been made, further examination may be made by X-ray. The quality of the weld metal is indicated in the photo (Fig. 13). How it exceeds the quality required may be judged by stating the code requirements, which are that plates 2 1/2 in. or less in thickness must be X-rayed by a sufficiently powerful X-ray apparatus and under a technique which will determine the size of a defect with a thickness greater than 2% of the thickness of the base plate. Note how the shielded carbon arc weld metal exceeds this requirement in the characteristic X-ray.

The shielded carbon arc process gives weld metal which meets Class I requirements and at a very low cost, these being obtained by the simplicity of preparation and weld methods.

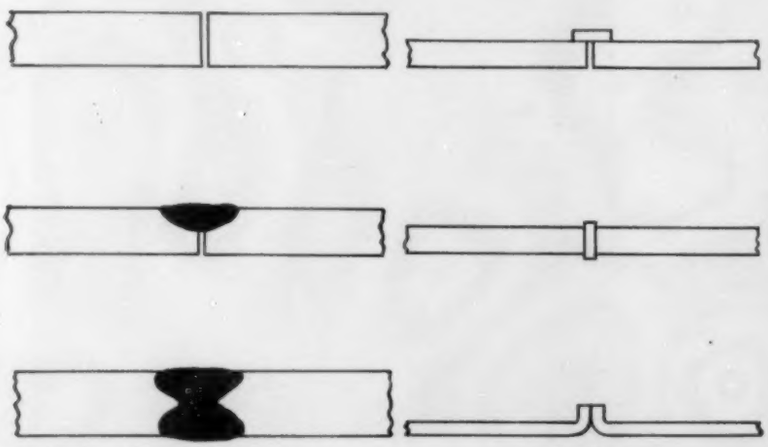


Fig. 9—(Upper) Plates. (Center) First Pass. (Lower) Two Passes

Fig. 10

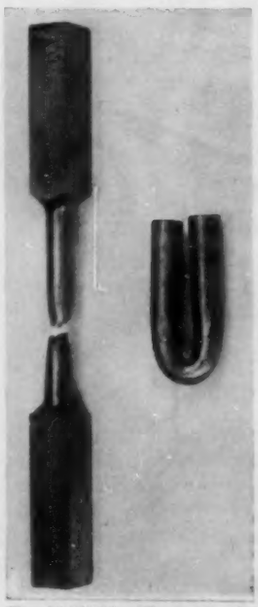


Fig. 11 (Left)—Elongation in 2 In. of Weld Metal Only
Fig. 12 (Right)—Free-Bend Test Showing Elongation of Extreme Fiber

Fig. 13—X-ray Photo

Rebuttal of Professor Doan's Discussion of the Paper, "The Governing Factors of the Performance of Mild Steel Electrodes," by Bela Ronay

THE paper, the subject of Professor Doan's discussion, was a summary of several reports submitted by the Welding Laboratory of the U. S. Naval Engineering Experiment Station to the Bureau of Engineering, Navy Department, Washington, D. C. It was limited to a 15-minute lecture period and obviously could not contain anything but a few statements of facts, as disclosed by the findings of the said laboratory.

It is regretted that the paper was not clear enough in explaining just what the Arcronograph charts indicate. The Arcronograph gives a historical or chronological record of the succession of the drops that travel from the tip of the electrode through the arc onto the work. It records the relationship of the volume, formation period and arc transit period of each drop. When, due to some disturbing factor present, a group of drops behaves in a manner different from the general trend, the result of such aberrations is indicated as a change of the amplitude, shift of phase and/or shift of location of the graph on the chart. Every one of the changes has a definite meaning, that may be expressed in terms of poor fusion, porosity or slag trapping.

Shrinkage cracks, of course, have nothing to do with electrode performance; they go hand in hand with poor engineering and lack of welding technique (as far as mild steel is concerned). For the detection of shrinkage cracks in welds one needs no X-ray; ordinary eyesight is usually sufficient.

Non-metallic inclusions certainly change the behavior of an electrode. Professor Doan claims that silicates are quiet in the bath of a steel furnace and at "similar" temperatures in the ladle. The chemical reactions in the bath of a steel furnace are not any too quiet and it is not claimed to know whether silicates act as pacifiers or not. There is no similarity between ladle temperature and arc temperatures; as a matter of fact, the temperature of the arc is over 1000°F. higher than that of the bath of an open-hearth furnace and almost 2000°F. higher than that of the quiet metal in the ladle. Professor Doan's ingenious drop testing method furnishes an excellent demonstration of the explosion-like force of non-metallic conglomerates in the arc. Reference is made here to the illustrations accompanying his paper showing a series of drops welded on a steel ribbon, interspersed with a spray of droplets, testifying of the explosion of some drops.

Successful manufacturers of covered electrodes have a pretty good empirical knowledge of the relationship of surface tension, viscosity and temperature of molten steel. This knowledge is the better part of their success.

They base their knowledge on such statements as are found in Neil Kensington Adams', "The Physics and Chemistry of Surface," Oxford 1930, page 153, Chapter 5, entitled, "The influence of temperature on surface tension."

To quote partly: "In fact, the surface tension invariably decreases with rising temperature, the only exceptions known being with a few substances over a restricted range of temperature. . . . In many cases the diminution of surface tension as the temperature rises is approximately linear over long ranges."

H. S. Taylor and others in the Treatise on Physical Chemistry, Van Nostrand, New York 1931, Chapter on Colloids, subhead, "Effect of temperature upon interfacial tension," sheds further light on the phenomenon of surface tension.

The simple method of decelerated deposition mentioned in the subject paper gives an excellent opportunity to study the relationship between surface tension, viscosity and temperature, and is recommended to the Professor's attention.

The difference between the resistivity of fully annealed wire and cold drawn wire amounts to a great deal more than 3%.

Manufacturers of electrode materials are fully aware of this fact and have been using for some time past certain types of magnetic testing apparatus to avoid supplying either type mentioned as neither is suitable for welding electrodes.

The temperature of the molten metal leaving the tip of a covered electrode is higher than that leaving the tip of a bare electrode; this statement is not an assumption, but a fact based oy the following proofs:

(*a*) The heat absorbed per unit length of electrode is greater for a covered electrode than for a bare-wire electrode of the same mass and composition. (Calculate from the formula $W = I^2Rt$.)

(*b*) The formation period of a single drop of metal at the tip of a covered electrode is on an average one and one-half times longer than that of a drop at the tip of a bare electrode. The molten metal at the tip of a covered electrode is exposed to the heat of the arc for a period almost 50% longer than does the molten drop at the tip of a bare-wire electrode, and since the mass of the drop at the tip of the covered electrode is greater only by 25% than that of a drop at the tip of a bare electrode of same diameter and composition, it having absorbed a greater energy input for a longer period will develop a correspondingly higher temperature.

(*c*) Most covered electrodes use reversed polarity, making the electrode the anode or the hot spot of the arc.

The author takes this opportunity to call attention to two papers concerning the principles and the use of the Arcronograph that will be published shortly. The papers will give the detailed data of comprehensive tests proving the usefulness of the Arcronograph.

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Repairing Small County Bridges by Arc Welding

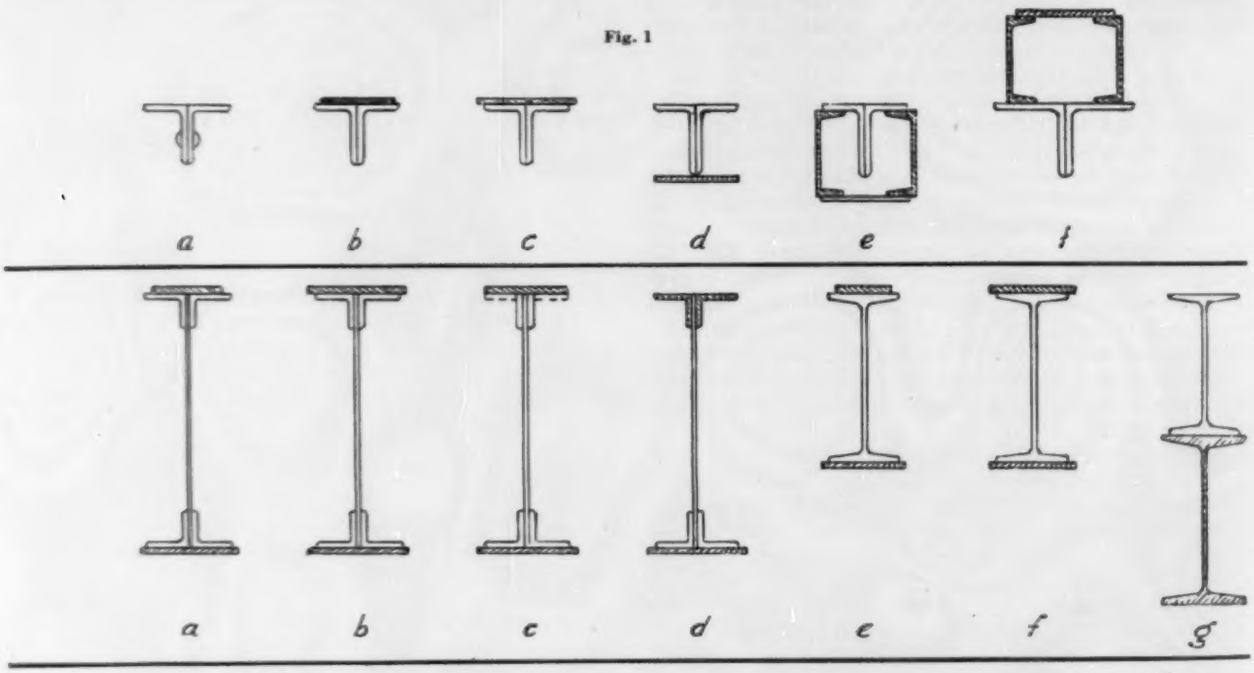
By HARRY K. ELLIS, C. E.

†Mr. Ellis is connected with the office of the County Engineer, Chester County Court House.

THE writer's first experience with welding structural members occurred in 1920. Inspection of a five-panel Pratt truss of 60-ft. span showed that one of the lower chord bars was broken completely off. As this bridge was on the principal highway between Philadelphia and Baltimore and carried very heavy traffic, it was necessary that something be done at once and, if possible, without shutting off traffic. I knew very little about welding, but had heard that it was used in automobile construction so decided to use it to repair this bridge. A gas welder was hired at a nearby garage and instructed to weld the bar, making every effort to get it to the same tightness as its mate. The work was successfully carried out and no further trouble developed until the fall of 1926 when it was discovered that the mate to the repaired bar had broken and that the repaired bar was carrying the entire load. As no inspection had been made between April 1924 and June 1926, when the broken bar was discovered, it is possible that the weld had carried double load for perhaps two years. I had the second bar repaired in the same manner as the first one had been, and it was still in good condition when the bridge was torn down in 1928. The performance of these welds, made as they were without proper supervision, convinced me that welding could be successfully applied to structural repairing, and I used it on several small jobs with entire success.

Since the beginning of 1932 arc welding has been in almost continual use in Chester County. The usual method is for the engineer to measure the bridge and to investigate its strength throughout. Almost invariably the stringers and floorbeams are found to be very weak. The trusses often have compression members with an l/r much too great and pins that are too small. Diagonals are found to intersect the chords at points far from

Fig. 1



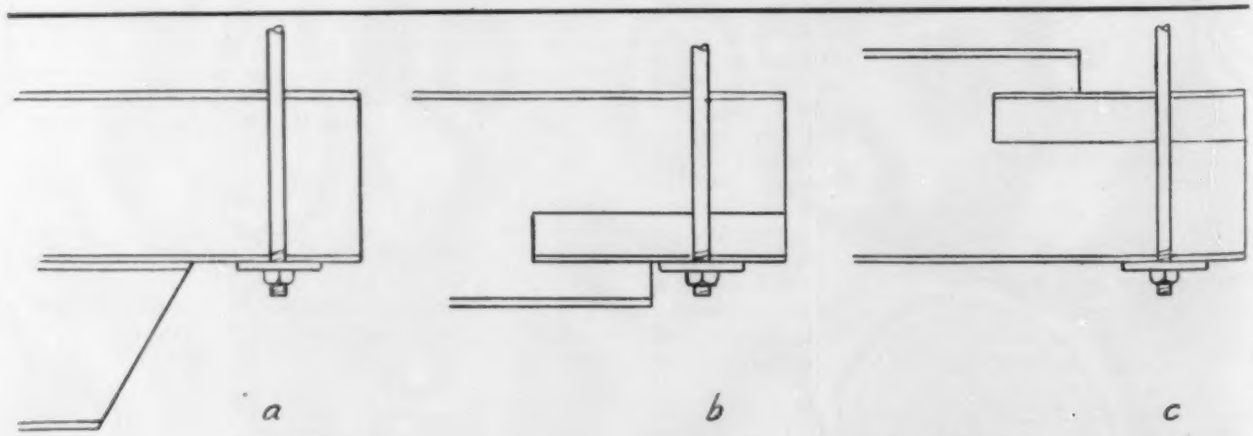


Fig. 2 (Center)

Fig. 3 (Bottom)

Fig. 4

Fig. 5

the panel point. End posts frequently are corroded entirely through at a point just below the floor line. All of these conditions may be successfully and economically repaired by means of arc welding.

Compression members of trusses are almost always composed of two angles riveted back to back as shown in Fig. 1*a*, or of two channels and a cover plate. The former usually are weak. The latter seldom need strengthening. Figures 1*b* and 1*c* show methods of strengthening such chords by adding plates to them. In Fig. 1*d* the plate is made of the same width and thickness as the top of the chord, thus changing it into an *H*-section. The method shown in Fig. 1*e* has proved very successful. Two channels are placed as shown, making the back to back distance about one inch greater than the width of the chord. A small continuous weld will transfer the stress into the channels and serves to keep water from getting between the old and new steel. Tie plates are welded at suitable intervals under the channels. Figure 4 shows a bridge reinforced in this way.

The method shown in Fig 1*f* was devised to strengthen the upper chord of a Warren truss in which the diagonals intersected the top chord about one foot apart. By placing the channels as shown the center of gravity of the chord was raised, thus reducing the eccentricity of the diagonal connections. Moreover the depth of the chord is much greater, offering greater resistance to bending. The area of the chord and the depth of the truss have both been increased, thus reducing the unit stress in the member.

The strengthening of weak pins is difficult, but has been done in several ways. In one case the entire lower chord, which was composed of eye-bars, was removed and replaced with a pair of channels which were welded to the end posts and hangers. By this means only the stress increment at each panel point is transferred through the pin, whereas with separate eye-bars the stress from one eye-bar passes into the next one through the pin. Thus, both bending and shear in the pin are much reduced. By welding the lower chord bars to each other or to the pin plate if they are on opposite sides of it, both shear and moment on the pin may be reduced. At the ends of trusses one may build up a support under the center portion of the pin, thus greatly helping a part that is almost always much overstressed. It is well to examine this point also for corrosion as the pins are small and I have found them reduced as much as $^1/_4$ in. in diameter. Since the section modulus of a pin varies as the cube of its diameter, this amount of corrosion is quite serious. For a $2^1/_2$-in. pin it would reduce the bending strength 27%.

Where channel chords are corroded through, our usual method of repair has been to burn out the corroded metal and to place a new channel back to back with the old one, plug welding it through the web and tack welding it wherever possible along the flanges. In this way the section may be restored to its original area, or increased if desired. The same method may be used to increase the strength of a chord composed of two channels and a cover plate or to reinforce a splice in such a member.

Stringers are usually 5-in. I-beams, spaced 30-in. to 36-in. centers and spanning from 10 to 14 ft. If in good condition, these may be increased about 20% in strength by welding them to make them continuous. If one additional line of beams is placed halfway between the existing stringers, the result is an increase in strength of 140%. If two lines are added, the increase is about

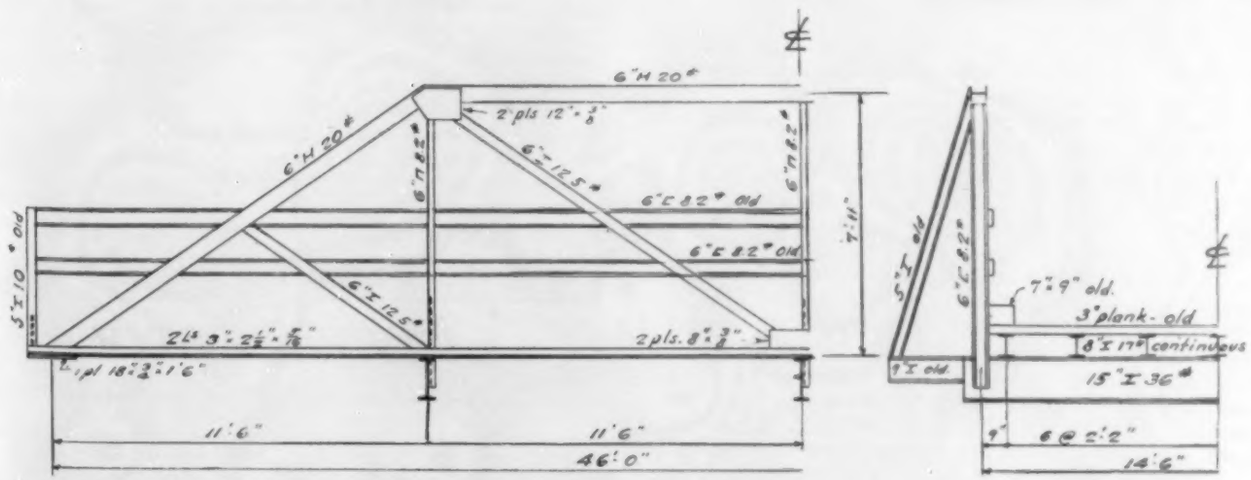


Fig. 6

Fig. 7

Fig. 8

260%. If the old beams are not in good condition and the grade of the road may be raised, it is usually better to scrap the old stringers and to use new beams of greater depth. The material from the old stringers may be used to repair other bridges where larger beams cannot be used, or for railings, railing posts, bracing or outriggers.

Floorbeams are almost always too small in section, and where plank decking has been used the upper flange is usually badly corroded. Figure 2 shows several ways that have been used to overcome these conditions. In Fig. 2*a* cover plates have been added to both flanges. The upper cover is made about one inch narrower than the flange, and the lower one about one inch wider to permit downhand welding. Figure 2*b* shows a floorbeam repaired in a similar manner except that a wide top cover is used requiring the more expensive overhead welding. In Fig. 2*c* the corroded outstanding legs of the top flange angles have been burned away and a plate of sufficient size welded fast. In Fig. 2*d* the corroded flange angles have been removed entirely and replaced with new angles of sufficient size that cover plates are not required. In using this method it is difficult to keep the web plate from buckling when the angles are removed so that we seldom use it for that reason. Figures 2*e* and 2*f* show I-beams strengthened in a manner similar to the methods mentioned. Figure 2*g* shows an excellent and economical method of repairing a floorbeam by welding another one to it. In contrast with the methods previously mentioned, it requires only two lines of welding, as against four required in the other methods. It can only be used, however, where the under clearance may be lessened.

Frequently it is better to scrap the old floorbeam and use a new I-beam. Figures 3*b* and 3*c* show methods by which the new material may be fabricated in the field so that the old hanger bolts may be long enough to be used. Figure 3*a* shows the end of a floorbeam reinforced as shown in Fig. 2*g*.

Bridges repaired under my supervision have varied greatly in age. The oldest one was built in 1867. Metal bridges built prior to 1890 were almost always of iron. Since then they were mostly built of steel. No trouble has been had in welding these metals, nor in welding iron to steel. Only one weld has been found broken, it being a railing post that had been welded upon very rusty metal in a corner where only one edge of the angle could be welded. The railing had been struck and bent and the weld at the foot of the post broken. On the other hand, a hanger was struck by a heavy truck and completely demolished, the iron being torn through at two places, yet the welds at the end of this member showed no signs of failure. Figures 7 and 8 show this member after being struck and after completion of repairs by welding.

I do not feel that welding has reached a point of perfection where any one with a welding outfit may be trusted to weld structural members. All our welding has been done by one firm and as far as possible by the same welder. This welder has become accustomed to our work and needs but little supervision. Qualification tests have been dispensed with as these jobs are too small for us to spend the money required to make them. To insure against poor welds, however, the welder's instructions are to make all welds at least 25% stronger than required. The cost of this additional welding has been found to be very small.

At the present time we are building six all-welded steel truss spans, the longest being 55 ft. 8 in. center to center of end bearings. While these are considered as temporary spans because of their narrow width, there is no reason to suppose they will not last for many years. Figure 5 shows the general make-up of one of these bridges and Fig. 6 a photograph of the same bridge.

These bridges are being built for 15-ton loading and, because of the times, as cheaply as possible. Floor planks are relaid wherever possible. The bridge seats are levelled up with grout and timber back logs installed. Railings and bracing are made from materials salvaged from other bridges when possible. Lower laterals run in one direction only in each panel. Curb logs are made from the top chord of old wooden bridges. Only one coat of paint has been given and that is a light gray, made up of mill ends by the paint factory.

The span shown in Figs. 5 and 6 cost as follows:

13,500-lb. structural steel, delivered,	$233.62
Labor, 240 hrs. a 0.40	96.00
Paint	4.41
Welding	138.60
Plank, hardware, etc.	22.04
Total	$494.67

This bridge replaced a covered wooden span. A farmer nearby removed the roof and siding and cleaned up the site for the material which we did not want. A gang of four unemployed men and one welder did all other work. The gang was composed of one draftsman, who had learned to handle a cutting torch and who did all the layout work; a rigger, a blacksmith and a clerk. No foreman was employed, the gang arranging the work among themselves. The low cost of the work is to a considerable extent due to their industry and careful planning. Welding Engineers, Inc., of Philadelphia, furnished the welder and all welding and burning apparatus.

Material for this bridge was delivered on the site at eleven A.M. on Monday morning and the work, except for a little cleaning up, was completed on the following Saturday night.

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